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HERBERT S. LANGFELD
PRINCETON UNIVERSITY

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THE PSYCHOLOGICAL REVIEW

EXPERIMENTAL ANALYSIS OF INSTINCTIVE BEHAVIOR [1]

BY K. S. LASHLEY

Harvard University

Some of the most remarkable observations in the literature of comparative psychology are reported in Kepner's study of Microstoma (**21**). This creature, related to the more familiar planaria and liver flukes, is equipped with nematocysts or stinging cells like those of the hydroids, which it discharges in defense and in capture of prey. In discharging, the stinging cell evaginates a threadlike barbed tube through which a poison is ejected. The striking fact about the creature is that it does not grow its own weapons, but captures them from another microscopic animal, the fresh water polyp, Hydra. The Hydras are eaten and digested until their undischarged stinging cells lie free in the stomach of Microstoma. The nettles are then picked up by ameboid processes of the cells lining the stomach and passed through the wall into the mesoderm. Here they are again picked up by wandering tissue cells and carried to the skin. The stinging cells are elliptical sacks with elastic walls, which are turned in at one end as a long coiled tube. In discharging, the wall of the sack contracts and forces out the barbed poison tube, from one end of the sack. The nettle cell can therefore only fire in one direction. When the mesodermal cell carries the nettle to the surface, it turns around so as to aim the poison tube outward. It then grows a trigger, and sets the apparatus to fire on appropriate stimulation.

[1] Presidential Address delivered before the New York meeting of the American Psychological Association on April 2, 1938.

When Microstoma has no stinging cells it captures and eats Hydras voraciously. When it gets a small supply of cells these are distributed uniformly over the surface of the body. As more cells are obtained they are interpolated at uniform intervals between those already present. When a certain concentration of the cells is reached, the worm loses its appetite for Hydras and, in fact, will starve to death rather than eat any more of the polyps, which are apparently not a food but only a source of weapons.

Here, in the length of half a millimeter, are encompassed all of the major problems of dynamic psychology. There is a specific drive or appetite, satisfied only by a very indirect series of activities, with the satisfaction of the appetite dependent upon the concentration of nettles in the skin.

There are recognition and selection of a specific object, through the sensory-motor activities of the animal. Later there is recognition of the undischarged stinging cell by the wandering tissue cells, and some sort of perception of its form, so that it may be aimed. The uniform distribution of the nematocysts over the surface of the body is a splendid illustration of a Gestalt, food for speculation concerning vectors and dynamic tensions.

Actually the phenomena of growth so closely parallel those of behavior, or rather behavior parallels growth, that it is impossible to draw a sharp line between them, and animistic theories of growth have been as numerous as mechanistic theories of behavior. Kepner, in fact, postulates a group mind among the cells of the body to account for the internal behavior of Microstoma, to me a *reductio ad absurdum* of mentalistic hypotheses, whether applied to worms or man.

Nevertheless, the naturalistic literature contains many such descriptions, made by careful and accurate observers, of instinctive behavior so complex and precise in its execution that we can only stand aghast at the inadequacy of our concepts of its mechanism. Its genuine relevance to the problems of psychology is well illustrated by the classical definition of instinct as the faculty which animals have instead of intellect which yet makes their behavior seem intelligent.

I am well aware that instincts were banished from psychology some years ago, but that purge seems to have failed of its chief objective. The anti-instinct movement was aimed primarily at the postulation of imaginary forces as explanations of behavior. It was only incidental that these had also been assumed to be constitutional. The psychology of instincts was a dynamics of imaginary forces and the anti-instinct movement was primarily a crusade against such a conceptual dynamism. Somehow the argument got twisted. Heredity was made the scapegoat and the hypostatization of psychic energies goes merrily on. Desires and aversions, field forces and dynamic tensions, needs and vectors, libidoes and means-end-readinesses have the same conceptual status as had the rejected instincts and, besides, lack the one tie to physiological reality which the problem of genetic transmission gave to the latter. The anti-instinct movement was a critique of logical method which failed of effect because it was aimed at a single group of concepts. Its history is a striking example of the lack of transfer of training or the futility of formal discipline.

Although the distinction of genetic and environmental influences has little importance in many fields of psychology, it is of real significance for problems of the physiological basis of behavior. This is true because information concerning the mechanics of development and the histological organization produced by growth is far more exact than any available data concerning the changes produced by learning. Fundamental principles of neural integration may be inferred from innate structure and the behavior dependent upon it. The plasticity and variability of learned behavior precludes any similar correlations with structural patterns.

In spite of a vast literature, there have been few systematic attempts to carry the study of instincts beyond the descriptive stage. Physiologists have been preoccupied with the mechanism of the spinal reflex and students of behavior either have been content to consider instincts as constellations of reflexes clustering around external stimuli or have neglected this side of the problem entirely and, like von Bechterew (**4**), considered

instinct as synonymous with motivation. There are actually two problems here, whose mutual relations are by no means solved. On the one hand are the more or less precise reactions to definite objects. The primiparous female rat gathers paper or other material and constructs a crude nest, cleans her young of the foetal membranes, retrieves the young to a definite locality, distinguishing them often from quite similar objects, assumes a nursing posture, and the like. These are reactions to specific stimuli. The problems which they suggest are those of neural integration; the nature of the stimulus which elicits the response, the pattern of motor activities by which a given result is achieved and, ultimately, the neurophysiology of the behavior.

In contrast to these precise sensorimotor adjustments is the activity which can only be described as reaction to a deficit. The restless running about of the mother rat deprived of her litter, the homing of the pigeon, or the inhibition of feeding responses in the chick removed from companions presents an entirely different system of reactions from those exhibited in the presence of litter, nest, or companions. This reaction to deprivation of some stimulus presents the typical problem of motivation.

For brevity I shall speak of the specific sensorimotor reactions, such as the spider's construction of a web or the courtship display of birds as the instinctive pattern, in contrast to the deficit reactions. The distinction is not always clear. When the humming-bird builds a nest she reacts specifically to lichens and fibrous material but the building to a definite form also suggests reaction to a deficit. The distinction is not a classification of activities but a suggestion of two different problems, reaction to an obvious stimulus and reaction in a situation where there is no external stimulus, or at least none as yet discovered, which is adequate to account for the observed behavior.

In many instinctive activities a further problem arises from the periodic appearance of both the mechanism and the deficit reaction. The migration of fishes, the seasonal nesting of birds, the receptivity of the female rat during œstrus, all

such periodic variations in responsiveness raise the problem of the causes of variation in the excitability of the sensori-motor mechanism and of the reaction to deficit. I shall designate this as the problem of activation of the instinct.

For a number of years we have been trying to discover the mechanisms underlying the reproductive behavior of animals. This activity was chosen for study because it presents the most precise instinctive behavior of mammals which can be brought under laboratory observation and because it exhibits a wide variety of problems, both of integrated behavior and of motivation. The work has developed in several directions. I shall summarize the results and attempt to relate them to some of the more general problems of the mechanism of behavior.

Innate Components of Sensory Organization

The majority of studies of instinct have dealt with the motor aspects of behavior or with the products achieved. The honey-dance of the bee (von Frisch, **14**, **15**), the nest of the oriole, the elaborate procedure by which the spider spaces the radial strands of the web (Peters, **29**) are so striking as to attract attention away from the problem of the sensory control of the behavior. The general outcome of such studies is familiar. The end attained, the web, the nest, is fairly constant and characteristic of the species. The series of acts by which it is constructed varies with every new element in the environment. Such stereotyped results attained by diverse means have formed the excuse for interpretations of instinct in terms of purpose or entelechy.

Granting the facts, there is still an alternative to such finalistic speculations, which are meaningless to those of us who ask *how* the result is attained. The apparent working toward a goal, which cannot be foreseen, is very difficult to express in terms of a motor mechanism, since the motor activities are variable and therefore cannot be interpreted as a predetermined sequence, run off automatically like an automatized habit. This variability in motor activity compels a search for some controlling factor and this might lie

in the characteristics of the animal's perceptual organization. It is possible that the nest, or other product of activity, presents a sensory pattern which is "closed" for the animal, in the sense in which this term has been applied to visually perceived forms. The nest might then be built by somewhat random activity, modified until it presents a satisfactory sensory pattern.

With this possibility in mind, a number of our experiments have been directed toward a descriptive analysis of the animal's sensory organization, when there has been no opportunity for modification by learning. The visual system is best adapted for such studies. Anatomically the system is very complexly organized, with the different parts of the retina projected with great accuracy upon the optic lobes or visual cortex (**23**). We have evidence that this precise anatomic pattern develops normally in the absence of any photic stimulation. Structurally it is probably the most elaborate portion of the nervous system so that, if anatomic differentiation has any functional significance, we should expect to find some innate functional organization in the visual system.

Studying the first visual reactions of rats reared to adulthood in total darkness, Hebb (**18**, **19**) has found that the animals respond immediately to objects, as contrasted with background. Something of figure-ground organization is immediately given. They learn readily a differential reaction to figures which cannot be explored in any way except visually. This means that the figures must be distinguished visually before association with motor reactions can occur. The animals show transposition for size and brightness when they have experienced only two absolute units in the series. This demands the immediate perception of relational properties.

Russell and I (**25**) have found that rats reared in darkness show an accurate discrimination of visual distance and, without training, regulate the force of jumping to the distance to be crossed. This involves a direct control of motor activity through some innate sensory organization.

These experimental results are in accord with the most careful studies of the congenitally blind children who have had

vision restored suddenly (Senden, **35**). So far as one can interpret the literature, these children distinguish figure from ground, distinguish objects as of different shapes, although they are unable to describe them, and have also some perception of distance.

In a series of experiments on discrimination of visual patterns I have found that the general characteristics of the figure-ground relation, as worked out by Rubin (**34**) and Wertheimer (**49**) for man, apply also to the rat. The evidence also points to the conclusion that the formation of the discrimination habit depends upon a perception of relations which is prior to the learning process. When a pair of stimuli is presented, one with positive, the other with negative reinforcement, the positive or negative reactions are associated only with that property of each stimulus which differentiates it from the other. A couple of experiments will illustrate the nature of the evidence. A group of animals was trained for 150 trials to choose an 8 cm. circle opposed to a black card; another group to choose a 5 cm. circle under the same conditions. All were then trained to choose the 8 cm. circle when opposed to the 5 cm. The previous training had no effect whatever upon the learning scores with the pair of figures. The property of size was not associated with the reaction so long as the object was alone. The same result is obtained when animals are trained with a single figure and tested for recognition of its form.

If an animal is trained to choose the larger of two circles he will spontaneously choose the larger of any pair of figures. The reaction is not differentiated for form. If he is trained with two different forms, he is undisturbed by wide variations in the size of the figures. So, in every discrimination habit the response is not to a specific pattern but to some property which distinguishes the two figures and which must be differentiated before the motor responses can be associated with it. Furthermore, when the nature of these differentiating properties is tested, they turn out to be relational; relative size, relative direction, proportions, and the like. Such evidence, I believe, disposes of the theory that reactions to relational

properties are due to irradiation of conditioned reactions to absolute properties.

These lines of evidence from the animal work support the conclusion already reached by the members of the Gestalt school, that the fundamental organization in perception is innate. And this organization has very definite characteristics, a preference, as it were, for certain specific arrangements of the physical elements of the stimulus.

Motor Action Based on Perceptual Organization

In only one of these observations is there a predetermined motor response; that is the regulation of the force of jumping to the distance seen. It is not necessary, however, that specific motor responses be directly elicited by the sensory organization, in order that the latter should be effective in directing the form of activity. Once motor reactions are associated with some aspects of the stimulus, or with an equivalent stimulus, the innate organization may exercise a selective action upon the various associated reactions. Thus the fluctuations of the staircase illusion may determine alternative associated motor responses, which have been built up by experience with three-dimensional situations and which themselves are certainly not responsible for the fluctuations of the illusion. Innate perceptual organization might similarly exercise a selective influence among motor activities not innately associated with the objects eliciting the reactions.

There is good evidence that animals without previous experience may give specific reactions to biologically significant objects and that the recognition or discrimination of these objects may be quite precise. I became interested in this problem first through observations on the brooding of the sooty terns. If these birds were given eggs of a related species to hatch they would invariably reject the foster children within a short time after hatching, throwing the chicks out of the nest and sometimes killing them. Strange chicks of their own species were accepted during the first few days of brooding. The chicks of the two species did not differ greatly in appearance, yet the discrimination was certain. I was unable to discover the sensory basis of the reaction, be-

yond getting indications that it depended upon a complex of stimuli, not wholly visual. The history of these birds was of course unknown but the number of individuals observed, considered in relation to the death rate of the colony, made it certain that some at least were dealing with their first brood.

Later Stone took up a similar problem, that of sex recognition, under conditions where the history of the animals and the patterns of sensory stimulation could be controlled. His studies of the effective stimulus to sexual activity are the most thorough available. More recently Borovski (**7**) has reported observations on the recognition of their eggs by gulls and Beach has completed a number of experiments dealing with the sensory control of the rat's reactions to her young. Although the adequate stimulus has in no case been completely defined, certain important general principles have come out of these studies.

When we first began work in the field it seemed probable that the exciting stimulus would turn out to be simple—an odor, a localized tactile stimulus such as that which induces the clasping reflex in the frog, or the like, and that this would initiate a chain of precise reflexes. Sensory controls have made this hypothesis seem untenable. Vision, olfaction, audition, tactile sensitivity of the snout and vibrissæ, of the paws or skin of the ventral surface can be eliminated singly without preventing the appearance of normal patterns of reaction when the stimulus object is first presented. The arousal of sexual excitement by the female in heat or the cleaning and first retrieving of the young is not dependent upon excitation through any one sense modality. The results of the experiments parallel those dealing with the performance of the maze habit, which is little if at all disturbed by the elimination of any single sense modality. Even the elimination of several sensory paths together may not interfere with the reaction. Thus in a familiar experiment Stone (**38**) observed copulatory activity in a male, reared in isolation, and with vision, olfaction, and tactile sensitivity of the vibrissæ and ventral skin eliminated. Similar results have been obtained by Beach in reactions of females to their young.

These results indicate either that we have missed some simple cue, through inadequacy of technique, or that the same pattern of instinctive behavior may be initiated through different sense modalities and patterns of stimuli. Swann's studies of olfactory discrimination (**44**) showed that a remnant of the olfactory bulb too small to be identified by gross dissection may mediate olfactory discrimination. This fact might be urged against Stone's conclusions, but Beach has confirmed Stone's observations with animals in which complete destruction of the olfactory bulbs was verified by histological examination. Like sources of error are improbable in experiments dealing with other sense modalities. Beach finds that desensitizing the lips and snout by section of the sensory root of the fifth nerve interferes with the retrieving of young by the female, but it interferes also with the finding and picking up of food, so that this operative control is inconclusive.

The experiments based on sense privation thus point to the conclusion that the exciting stimulus in instinctive recognition of mate or young is not mediated exclusively by any one sense modality.

A second experimental method for analysis of the adequate stimulus has consisted of the successive elimination of properties of the stimulus object in an effort to determine the minimal characters which will elicit the normal pattern of response. Two points have come out clearly in this work. The first is that a wide range of variation in any property of the stimulus is possible, without destroying its effectiveness.

Borovski (**7**) found that gulls would retrieve eggs to their nests from some distance. He substituted other things for the eggs. The birds retrieved objects of various sizes, weights, textures, and specific heats, ranging from small pebbles to potatoes and billiard balls. But any marked departure from a rounded or oval form led to rejection of the substitute. Cubes, angular stones, and the like were not retrieved. Texture also seemed important, since mudballs were rejected. I have observed that the terns are greatly disturbed by a lump of mud or wax stuck on an egg and

distorting its form, although painting or dyeing the eggs in varigated colors is without effect. The adequate stimulus of the egg may thus be defined as a rounded object of certain limited size and texture, and this, in the setting of the nest, elicits specific retrieving, cleaning, and brooding behavior.

Stone (37) could define the stimulus to sexual excitement in the male rat only as an object within certain limits of size, exhibiting a definite jerking movement. The analysis of the female's recognition of her young is still less complete, but size and surface texture seem to provide the chief cues by which the young are identified.

Thus far no investigator has found any single property of the stimulus object which cannot be varied within limits without disrupting the reaction. The stimulus is not a single characteristic color or odor, but seems to be a pattern, having the same characteristics of organization which we have found in studies of visual discrimination of objects. The complete analysis of sensory control of reactions to the mate or young seems scarcely less difficult than the problem of sensory control of homing has proved to be. The experiments thus far carried out have scarcely done more than emphasize the need for exhaustive studies in the field.

It is really imperative that we make a serious effort to define the adequate stimulus, not only in studies of instinct but equally in studies of reflexes and of learning. Psychological theories based upon the relations of stimulus and response remain sheer nonsense so long as the stimulus is defined only as whatever the experimenter puts in front of the animal. We have gone far enough in this work to be sure that the animal rarely reacts to what the experimenter regards as the stimulus. In any complex situation the true basis of reaction can be discovered only by systematic variation of all the parts and properties of the supposed stimulus.

The second point of significance revealed by studies of the stimulus to instinctive behavior is that the effective properties of the stimulus vary with the total situation. The primiparous mother rat will retrieve a number of objects having some resemblance to infants, selecting them from

among food objects and nest materials. Temperature, odor, shape, color, surface texture, brightness and size may be somewhat altered without interfering with retrieving. But in the nest the subsequent behavior toward the objects varies with their character. The mother may start to lick a stuffed skin which she has retrieved and discover the stitches in it. She promptly pulls at these, soon removes the sawdust and discards the skin. The nest situation plus the retrieved object calls out new responses and if the sensory pattern of the substitute stimulus does not conform to the requirements of this total situation, the normal course of behavior is disrupted. I have observed that the sooty tern is stimulated to assume the brooding posture by the contact of a chick under the breast but the reaction is only momentary unless the bird is on its own familiar nest.

The accumulated observations suggest that the instinctive behavior is dependent upon a complex of stimuli. Some of the reactions are elicited only by the total integrated pattern. Others may be aroused by single elements of the stimulus and interfering reactions are likely to be excited when the stimulus has abnormal traits which themselves elicit other instinctive or habitual responses.

Such an interplay of specific sensory demands may well form the basis of apparently purposive activities. The nest of the rat is a very primitive affair in comparison with the structures built by many animals. Kinder (**22**) found that animals which had had no previous experience with any nest materials, collected material as promptly and built nests indistinguishable from those constructed by experienced animals. Sturman-Hulbe (**43**) found little evidence of a basis for selection of materials beyond ease of manipulation and, possibly, specific heat. The range of materials tested was slight, however.

The actual construction of the nest, that is the determination of its form, seems to meet the requirements of low heat conductivity underneath, contact with the body at the sides, and, less consistently, exclusion of light. The arrangement of optimal conditions in these three respects dictates the form of

the nest. The combination of sensory factors is fairly clear and is consistent with the hypothesis of perceptual control that I have suggested. That they are in any sense relational or involve any perception of form is doubtful, in the case of the rat, however.

The available evidence is not sufficient to establish the thesis that the perceptual organization of the animal determines the goal of behavior but the studies of the rat do suggest control by a complex sensory pattern. What the situation is in the case of more elaborate construction, such as the nests of the weaver birds, can only be determined by actual analysis of the process of construction.

The Distinction of Reflex and Instinct

The changes in the character of the responses and in the nature of the adequate stimulus under different environmental conditions, for example the cleaning of the young in the nest and not during retrieving and the like, are, in a sense, a confirmation of the chain-reflex theory of instinct. It is true that the instinctive behavior creates situations which in turn serve as stimuli to further activities. To dismiss the activity as reflex is, however, to ignore its characteristic features.

Many writers have attempted to differentiate between reflex and instinct, but the final criterion has been only a vague difference in complexity. Our conception of the nature of reflex is derived largely from avoiding reactions elicited by protopathic stimuli and from the muscle-shortening reflexes. These are elicited by a localized group of sensory endings. Locus, intensity and modality of the stimulus are its determining properties. In contrast to this, sexual and maternal behavior seem chiefly determined by the pattern or organization of the stimulus, with locus of incidence upon the sensory surface or sense modality secondary. In this respect the instincts present the organismal problem as the reflexes do not. This difference in the nature of the adequate stimulus justifies, I believe, the retention of the term instinct to stress the importance of the problem of sensory organization.

The Activation of the Sensorimotor System

Many sensorimotor reactions are performed apparently as soon as the growth of essential nervous structures is completed. The pioneer studies of Herrick and Coghill (**20**) marked the way for the many later investigations correlating the appearance of early reflexes with the growth of nervous connections. In many of the early reflexes the mechanism is capable of functioning as soon as growth is completed. But there are, also, many activities which appear only at some interval after the completion of neuron growth. The work of Tilney and Casamajor (**45**) suggests that the late appearance of some of the so-called delayed reflexes or instincts may be due to late myelinization of tracts, but the maturation of instinct as studied by Breed (**8**) and Bird (**6**) is probably due to a diversity of causes in which neural growth is less important than general development of muscular strength and control.

Reproductive behavior presents a unique situation among instinctive activities in that it is delayed long after the development of the nervous system and is conditioned by the attainment of sexual maturity. Recent studies of hormonal activation of sexual behavior raise important problems, both of neural integration and of motivation. The work of Steinach (**36**), Stone (**37**) and a number of more recent investigators shows the dependence of the behavior of the male upon the testicular hormone. Many studies show the importance of endocrine products in the regulation of the œstrus cycle and the relation of the behavior of the female to this cycle. The experiments of Wiesner and Sheard (**53**), Riddle, (**31**, **32**), and others indicate something of the dependence of maternal behavior upon pituitary secretions.

The interrelations of the hormones are complex and the literature upon this subject is vast. I shall not take time to review the evidence on the physiological action of the various hormones. More important for us who are interested in behavior than the details of the biochemistry and interaction of the endocrine products is the question of how they act to induce the appearance of specific patterns of behavior. The

introduction of male hormone into the blood stream somehow sensitizes the animal to the stimuli presented by the female in heat. What is the mechanism of such sensitization?

The difficulty of the problem is enormously increased by the variability of behavior under normal conditions. There seems to be no item of behavior except parturition and the removal of the fetal membranes from the young which is wholly restricted to the mother rat. Norman has found that nests are sometimes built and young retrieved in a manner indistinguishable from that of the best mothers by virgin females and even by males. Stone and others have observed female mating reactions on the part of normal males and Beach the masculine behavior of normal virgin females. The mere observation of such behavior in experiments involving injection of a hormone therefore does not justify the conclusion that the hormone is responsible for the behavior. There are distinguishing characteristics of what we have considered as normal behavior. The parturient female collects her young into the nest immediately or within a few hours after their birth. Virgin females and males show such behavior only after much longer exposure to young, often with an intervening period during which the young are devoured. It is not impossible to establish definite criteria by which hormonal effects may be recognized but the necessary criteria are quantitative rather than qualitative. The validity of the criteria employed by earlier workers is somewhat called in question. We can only consider the problem of activation on the basis of observations which should be checked again with more attention to the range of normal variation.

With this reservation it seems worth while to consider the mechanism of activation, if only to define the problem more clearly.

1. Does the hormone stimulate the growth or formation of new nervous connections, as the chemical organizers in Spemann's experiments stimulate differentiation of structure? A number of observations may be urged as arguments against this possibility. Castration abolishes the male reaction. Injection of the male hormone may restore it promptly and

it may be repeatedly revived by repeated injection of the hormone. It is unlikely that each of these repeated activations involves a renewed growth with intervening degeneration of the mechanism. In the experiments of Wiesner and Sheard retrieving of the young grew less persistent as the young approached weaning age and began to venture from the nest. The retrieving reaction could be restored to its initial vigor, either by injection of pituitary hormones or by giving the mother new-born young to nurse. The responses to the younger infants were apparently immediate. We cannot ascribe the initiation of neuron growth to this stimulus and so have no reason to assume that the hormone produces such an effect. This and other evidence points to the conclusion that the neural mechanism is already laid down before the action of the hormone, and that the latter is only an activator, increasing the excitability of a mechanism already present.

2. Does the hormone act merely by increasing the general excitability of the organism? Reduced sexual activity during starvation or physical illness (Stone, **40**) and the fact that male hormone increases the excitability of the sympathetic system as measured by vasomotor reflexes (Wheelon and Shipley, **50**) lends plausibility to this assumption. I have found, however, that castration does not alter general activity for a month or so, nor is there other valid evidence for a reduction in general excitability which is common to castrated males, females in the diœstrum, and nonparturient females, which should be the case if the hormones acted as general excitants. Finally, the strongest argument against this hypothesis is the apparent specificity of the different hormones for different patterns of behavior as illustrated by Moore's reversal of sex behavior (**27**) by interchanging the gonads of the two sexes.

3. The hormones induce specific changes in various organs, such as the vascular changes in the uterine mucosa, the rapid enlargement of the testis, or lactation in the mammary glands. It is possible that these altered states initiate sensory impulses which facilitate the mechanisms of the secondary sexual reactions. This is the mechanism implied in Moll's evacuation theory (**26**) of the sex drive and in the ascription of

various phases of maternal behavior to lactation. The suppression of the œstrus cycle and of receptivity in the female rat during lactation, and the correlation of sexual behavior with phases of the œstrus cycle suggest an elaborate interplay of such mechanisms.

The evidence against this somatic sensory reinforcement is rather compelling, however. Stone tested the evacuation theory by removing as much as possible of the reproductive system from males and observing their behavior after treatment with male hormone. He found sexual excitability, responsiveness to the female in heat, in castrated animals from which all of the accessory reproductive glands had been removed, leaving no anatomic basis for the tension of accumulated secretions assumed as the source of sensory reinforcement in the evacuation theory. Several investigators (Wiesner and Mirskaia, **52**) have reported the hormonal induction of œstrus without the induction of mating behavior. Ball (**2**) has observed the normal signs of sexual excitement in females from which the uterus and vagina had been removed. Wiesner and Sheard have reported and Norman has confirmed the fact that normal retrieving of young occurs in parturient females from which the mammary glands were removed in infancy. The mechanical stimuli of lactation therefore cannot be an important factor in the induction of this phase of maternal behavior.

In each of these experiments the organs to which the function of sensory reinforcement would naturally be ascribed have been removed without abolishing excitability to the appropriate stimuli. Still more conclusive evidence on this matter comes from instances of reversal of sexual behavior. In gynandromorphic insects with head of one sex, thorax and abdomen of the other, sexual behavior is reported to follow the sex of the head, not that of the reproductive system (Whiting, **51**). Reversal of sexual behavior in hens with tumors of the ovary has long been known (Morgan, **28**). In the experiments of Moore the gonads were interchanged between male and female rats and corresponding reversal of

behavior noted, the feminized males retrieving young and the masculinized females showing male behavior.

Such observations and experiments seem to preclude the evacuation theory of sexual activation and to minimize the importance of any sensory reinforcement from somatic organs in the production of specific reproductive responses. Of course they do not rule out all possible peripheral mechanisms which might provide effective facilitation for specific reflexes. Certain possibilities have not yet been explored, such as that of an altered temperature control during pregnancy which might precipitate nest building, as Kinder (**22**) has suggested, or localized changes in vasomotor reflexes which might alter local cutaneous sensitivity. Nevertheless, the organs showing greatest structural changes under hormone influences and those to which sensory facilitation has been ascribed have been removed without destroying the secondary sexual reactions and the observations on reversal of sexual behavior make it pretty certain that somatic sensory impulses cannot be the determiners of specific reaction patterns.

4. There remains only the last alternative, that the hormones act upon the central nervous system to increase the excitability of the sensorimotor mechanism specifically involved in the instinctive activity. Direct evidence for this is lacking and we have no conception of the way in which various organic compounds might exercise a selective effect upon specific nervous elements or schemata. There are, however, many instances of the restricted influence of drugs, both upon localized structures, as in the case of strychnine, and upon psychological functions, as in the action of mescal. There is also some slight evidence for the local sensitization of nervous tissue to organic toxins, with a selective action of later doses upon the sensitized tissue. The hypothesis of a specific action of the hormones upon nervous organization is therefore not without parallel in the literature of pharmacology. The problem here is clear enough. Techniques of direct investigation, as by serological tests of the affinity of specific structures for different hormones, are still lacking.

Neural Structure and Instinct

Gross localization.—The probable locus of action of the hormone within the central nervous system leads to the question of the neurological basis of instinct. The notion of a sharp distinction of levels must be abandoned. Zeliony (**55**) and Culler and Mettler (**10**) have demonstrated the possibility of conditioning in the decorticate animal, so that the cerebral hemispheres are no longer to be regarded as the exclusive seat of the learning process. Instinctive activities are also not exclusively a function of subcortical structures. In submammalian forms many complicated instincts can be carried out in the absence of the forebrain, as illustrated by Rogers' studies of the reproductive activities of decerebrate pigeons (**33**). In these birds such complex learning as is required by differential reaction to visual forms is also independent of the forebrain (Gemelli e Pastori, **16**) so that these animals do not provide evidence for a separate localization of instinct and learning. In mammals instinctive activities may suffer severely from total or partial decortication. I have found that the rat's reactions to visual distance are disturbed by injuries to the visual cortex but are unaffected by extensive destruction of the optic centers of the thalamus and midbrain. Mating behavior has not been observed in male rats lacking more than half of the neocortex. It is difficult to keep such animals at a normal level of general vigor and their impotence might be ascribed to lowered vitality. They usually fail, however, to show any specific reactions to cage mates and in this respect are quite different from animals which are under-nourished or ill. Stone (**41**) has found normal mating behavior in male rabbits with large cortical lesions and Brooks (**9**) in completely decorticate male and female rabbits, so long as the olfactory system remains intact. The difference between the rat and rabbit thus seems to correspond to the degree of specificity of the adequate stimulus in the two genera. Brooks has reported normal mating in rabbits deprived of olfactory bulbs and with the neocortex intact. This confirms our conclusion concerning alternative effective stimuli.

The studies of Beach (3) show the dependence of many aspects of maternal behavior upon the cortex. Using such criteria as the time of initiation of nest-building before parturition, the removal of the fœtal membranes, grade of nest, retrieving, and the removal of the nest and young from unfavorable conditions, he has compared the performance of normal mothers with that of others having various cerebral lesions. Practically every item of the behavior showed deterioration in proportion to the extent of cerebral injury.

None of the primary reactions dropped out as a result of the cerebral lesions. Collecting nest material, nest building, cleaning the young, retrieving were observed in all animals, but in case of those with extensive lesions the activities were not fitted together into an effective organization. Nests were poorly constructed and inadequate as protection to the young. One or two of the litter might be cleaned, the rest left to die in the fœtal membranes. In retrieving tests the young were carried about but not collected into a single group, and so on.

The results of this study are of especial importance in emphasizing, by contrast, the degree of integration of activities in the normal pattern. Dunlap (13) has averred that there are no instincts, although there is instinctive behavior, meaning by this that such categories as maternal behavior are created by the observer out of an aggregate of activities which, in themselves, have no physiological coherence. The analysis of cerebral function in maternal behavior favors an opposite interpretation. The partially decerebrate mother shows all of the component activities which are revealed by the maternal behavior of the normal animal, but these elements are so poorly coordinated that she cannot rear her litter. The normal pattern of maternal behavior involves a total integration of the component activities which makes it a functional unit and in mammals this unity is given by the activity of the cerebral cortex.

Histologic structure.—In the visual system there is a high degree of precision in the topographic arrangement of the fibers. A statistical study of the distribution of normal cells

in the lateral geniculate nucleus shows after lesions in the visual cortex that the axons which reach the cortex reproduce exactly the relative spacial positions of the cells in the nucleus; that is to say, the concentration of cells is uniform, right up to the edge of a degenerated area in the nucleus. But this accuracy of growth is apparently rare and it constitutes in the visual system not a precise set of sensorimotor connections, but a cortical field in which the spatial relations of retinal excitation are reproduced and whose parts are still equipotential for the integrative processes.

Experimental studies of nerve growth and regeneration seem to establish the fact that in general there is little specificity in the connections of individual fibers. The transplantation experiments of Detwiler (**11**) and of Weiss (**47, 48**) show that the distribution of the fibers to the muscles may be quite random and yet coordinated movements are effected as soon as growth is completed, without any opportunity for the intervention of practice to establish the patterns of integration. This, rather than the precision of the afferent visual pathway, must represent the usual state of affairs in the growth of nerves and tracts. No exact sensorimotor connections are established, yet the instinctive reactions may have a high degree of precision.

In general the neurological problems which have arisen in the study of instincts are identical with those of cerebral function in learning. The same questions of equivalence of stimuli, of substitute responses, and of similar effects of various cerebral lesions appear, whether the activities are innate or learned. We are no nearer to an answer to such questions in one case than in the other, but I believe that there is more hope of solution of these problems through the study of instincts than of learning.

The Physiology of the Drive

I have reviewed the evidence that the endocrines must act directly upon the central nervous system to activate the instinctive pattern. The same evidence may be applied to the problem of reactions to deficit. The experimental studies

have in fact dealt with gross activities such as retrieving or mating which involve both reaction to deficit and specific sensorimotor patterns, both preparatory and consummatory activity. This means that the various motivational factors observed in maternal behavior cannot be ascribed to somatic sensory reinforcement, any more than can the hormonal activation of the reactions.

Most of the current theories concerning the nature of primitive drives have been derived by analogy with the hunger mechanism and assume some continued visceral activity, comparable to the contractions of the empty stomach, as the source of masses of excitation whose irradiation in the nervous system increases the general responsiveness of the animal. This analogy has certainly been overworked, especially as it is by no means assured that hunger motivation is itself synonymous with the hunger pangs. The work of Richter (**30**) and Wada (**46**) shows a correlation between rhythmic bodily activities and hunger contractions, but the activities of the animal under hunger motivation are not rhythmic. The rat in the maze does not stop running between hunger pangs. Even for hunger motivation we must assume, I believe, some source of continued excitation which is no more than activated by the hunger contractions.

When the theories of motivation by somatic sensory facilitation were developed, there was little evidence that activity could be sustained within the central nervous system. The maintenance of tension or activity through some form of circular reflex was more in accord with the conception that all excitation must pass over immediately into motor response, as first formulated by Dewey (**12**). The recent demonstration of recurrent nervous circuits, perhaps capable of indefinite reverberation, by the anatomic and physiologic studies of Lorente de Nò, relieves us from the necessity of finding a peripheral mechanism to account for the maintenance of activity or for the dynamic tensions which are implied by the phenomena of motivation. The studies of the sexual and maternal motivation strongly suggest a central nervous mechanism which is merely rendered excitable by hormone

action. What this means is that the seeking activities or reactions to a deficit, such as are measured by the obstruction method, are not a reaction to a continuous peripheral stimulus, such as is assumed in the evacuation theory, but are the expression of some central nervous activity or state.

The relation between the reactions to deficit and the excitability of the specific patterns of behavior is obscure. It is generally stated that the drive is first aroused, as by endocrine action, and that this, in turn, causes the appearance of the instinctive sensorimotor reactions. An increase in the excitability of sexual reactions is accepted as evidence for intensification of the drive. But the phenomenon actually observed is only a more ready excitation of specific responses. There is no need to postulate an extraneous drive to account for the fluctuations in the threshold of such reactions. The mechanism is present and under the influence of the hormone or of excitation by an adequate stimulus its excitability is increased.

Only in cases of reaction to a deficit is there any justification for introducing the notion of a drive as a source of facilitation. An increase in general activity or in exploratory behavior indicates an increased responsiveness to stimuli not obviously related to the specific sensorimotor patterns of the instinctive behavior. There is also inhibition of reactions to other stimuli, as when the chick removed from companions refuses to eat. This is a selective facilitation of activity and the facilitation originates with the organism. Does it call for the postulation of some source of energy apart from that of the specific sensorimotor patterns? The evidence indicates that the facilitation is probably independent of somatic stimulation and is of central nervous origin. Stimulation of an instinctive pattern will increase the intensity of the apparent drive. Thus sexual excitement in the male rat is aroused only by the very specific pattern of the female in heat, but once the animal is so excited, he will respond to less definite patterns of stimulation. The waning retrieving activity of the female is intensified by supplying her with a younger litter. Motivation of the hungry animal in the maze

is really effective only after the maze has been associated with the getting of food. In these cases the apparent motivation seems to derive from a specific sensorimotor mechanism.

I suspect that all cases of motivation will turn out to be of this character; not a general drive or libido, or disturbance of the organic equilibrium, but a partial excitation of a very specific sensorimotor mechanism irradiating to affect other systems of reaction. In his dynamic psychology Woodworth (**54**) suggested that habits might acquire dynamic functions, that a mechanism might become a drive, as he expressed the matter. I should carry this notion a step further and suggest that physiologically all drives are no more than expressions of the activity of specific mechanisms.

Summary

I have reviewed the material on reproductive behavior chiefly to illustrate what seem to me the fundamental problems of instinct. Practically the whole of physiological theory concerning the integration of behavior, whether of spinal reflex or of speech, is based upon inference from the relations of stimulus and response. Instinctive behavior raises questions of the nature of the adequate stimulus which seem to differentiate such activities sharply from spinal reflexes. An essential first step toward an understanding of the mechanism of instinct is the analysis of the properties of the stimulus situation which are really effective in arousing the behavior. This has proved to be a very difficult task, ramifying into all of the problems of perception. Understanding of the motor activities seems to hinge upon these perceptual problems. Little of the behavior can be described in terms of stereotyped movements; rather the whole repertoire of learned and reflex movements may be elicited until some definite sensory pattern is produced. The phenomena are identical with those from which I have inferred the equivalence of reactions and Bethe (**5**) the principle of "sliding coupling."

I feel that the problem of motivation is also closely identified with the problem of the specific patterns of instinctive response. Hormone action, or reinforcement by sensory

impulses from the viscera, seems to do nothing more than activate some central nervous mechanism which maintains excitability or activity. There is no good reason to assume that this mechanism is distinct from the sensorimotor organization which is later active in the consummatory reaction. The current trend in social psychology and psychopathology is to elevate the drive to the position formerly occupied by instinct, as some general motivating force apart from specific sensorimotor systems. Actually the term is nothing more than a general designation of reactions to deficit and its hypostatization as a real force can only blind us to the fact that each such reaction constitutes a special problem involving, perhaps, a unique mechanism.

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AN ALGEBRAIC ANALYSIS OF CONDITIONED DISCRIMINATION IN MAN

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1. Introduction

The human being upon entering a conditioning experiment relinquishes none of his normal controls over behavior, except to the extent that his cooperation with the experimenter requires him to keep some of them in abeyance. He anticipates the stimuli which are to appear, and he prepares himself in certain ways to react to them. Experimenters are increasingly calling attention to the importance in conditioning of set, attitude, and verbal processes. While it has sometimes been supposed that these factors necessarily make the conditioning experiment with the human subject something different from what it is with animals, this difference may be one only of degree. There are sufficient similarities between the responses of organisms as diverse as dog, monkey, and man, when experiments are done with similar stimuli and under similar circumstances, to make the comparative method instructive (9). Furthermore, it cannot be assumed because animals do not talk that they are incapable of preparatory adjustments such as in man would be classified as set or *Aufgabe*. The difference between the maze-wise rat and the naive rat in a novel maze is a case in point. But the human subject, because he is able to follow instructions and report on his responses, is an unusually convenient organism to use in studying situations in which preparatory set is an important factor.

In a series of reports concerned with discriminatory con-

ditioned eyelid reactions (**5**, **6**, **7**, **8**) [1] the influence of instructions on the course of discrimination has been the major object of study. The present paper attempts algebraic analysis of the results of these experiments, in order to arrive at a quantitative interpretation of the importance of the different controls affecting the discriminations.

2. Tendencies Inferred to Affect Responses

Preparatory adjustments are influenced by all the reflex, habitual, verbal controls which affect behavior. The ability of the subject to follow specific instructions is interfered with by emotional excitement, muscular tension, prior habits, and so on. For purposes of algebraic analysis it is necessary to introduce an arbitrary simplification of these processes.

In a conditioning experiment complicated by verbal instructions it is possible to assume as constant a variety of background factors, and then to direct attention to changes associated with reinforcement and non-reinforcement, on the one hand, and with instructions to react or not to react, on the other. Positive and negative conditioning tendencies, and positive and negative voluntary tendencies, may be inferred as determining the changes in behavior which are observed. In a discrimination experiment the preparatory adjustments are made somewhat more difficult by the necessity for selective reaction; instructions to react to one of the stimuli, for example, will lead to some tendency to react to the other. This process is called generalization and refers to the fact that the second stimulus always shares somewhat in any change in response tendencies with respect to the first. The positive and negative conditioned and voluntary tendencies, with their generalizations, are listed in Table 1, with the symbols chosen to represent them. The capital letter *C* is used for conditioning tendencies, the capital letter *V* for

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voluntary tendencies. The subscript p is used for positive tendencies, *i.e.*, tendencies leading to increases in responses in reference to the stimulus under consideration, and the subscript n is used for negative tendencies, leading to reduced response.[2] The generalized tendency is symbolized like the original tendency on which it is based, except for the prime (′) mark. That is to say, if a positive conditioned tendency (C_p) is built up by reinforcement to one stimulus, there will be a corresponding tendency (C_p') to yield conditioned responses to the non-reinforced stimulus. The table represents an over-

TABLE 1

INFERRED TENDENCIES AND THE SYMBOLS CHOSEN TO REPRESENT THEM

Tendencies Inferred to Influence the Percentage Frequency of Response	Symbols: Tendency Influencing Responses to the Stimulus under Consideration	Symbols: Generalized Tendency Affecting Response to other Stimulus
Conditioned positive tendency, due to reinforcement	C_p	C_p'
Conditioned negative tendency, due to non-reinforcement	C_n	C_n'
Voluntary positive tendency, due to instructions	V_p	V_p'
Voluntary negative tendency, due instructions	V_n	V_n'

simplification, but the eight variables lend sufficient complexity for purposes of preliminary analysis. Each of the variables may be considered a component of the preparatory adjustment of the organism affecting response to the conditioned stimulus.

3. THE DATA AS SCALED PRELIMINARY TO TREATMENT

In Table 2 are summarized the more important results from the series of experiments under consideration. All of the experiments consisted in conditioning the eyelid responses of college students by reinforcing an illumination change with a puff of air to one cornea. The positive stimulus was a light on one small rectangular window invariably reinforced by the

[2] There are no implications regarding the physiology of positive and negative tendencies.

air-puff; the negative stimulus was a similar illumination change appearing on an adjacent window, never reinforced by the puff of air. Subjects had no difficulty in distinguishing between the stimuli, so that the problem of thresholds of perception is not involved (5). The designation positive and negative with respect to the stimuli refers to the tendency to develop conditioned responses to the reinforced stimulus at a

TABLE 2

SUMMARY OF DATA TO BE SUBJECTED TO ALGEBRAIC TREATMENT

Groups with Summary of Instructions	Percentage Frequency of Response		
	Day 1	Days 2–3	
	Positive Stimulus	Positive Stimulus	Negative Stimulus
Group S. Simple conditioning only. 63 subjects (3)	46	80*	None
Group A. Simple conditioning on Day 1. Discrimination without added instructions on Days 2 and 3. 10 subjects (6)	47	75	37
Group B. Simple conditioning on Day 1. Information about positive and negative stimuli before Day 2; no instructions with respect to response. 10 subjects (6)	57	74	26
Group C. Simple conditioning on Day 1. On Days 2 and 3 instructed to respond to positive, to refrain from responding to negative stimulus. 10 subjects (7)	37	90	13
Group D. Simple conditioning on Day 1. On Days 2 and 3 instructed to respond to negative, to refrain from responding to positive stimulus. 10 subjects (7)	27	71	94
Group E. Simple conditioning on Day 1. On Days 2 and 3 instructed to refrain from responding to either positive or negative stimuli. 10 subjects (7)	44	55	19

* Group S, from an earlier series of experiments, received 50 reinforcements per day on each of two days, whereas the other groups received 60 reinforcements on Day 1, and 30 each on Days 2 and 3. On Day 2 Group S averaged 76 per cent. This has been raised arbitrarily to 80 per cent in the table to compensate for the difference in number of reinforcements.

higher frequency than to the negative stimulus. The extent of conditioning is measured for the present purposes by the percentage of trials on which conditioned responses appear. Thus if a stimulus is presented 100 times and conditioned responses are given to 75 of these, the extent of conditioning will be indicated as 75 per cent. Voluntary tendencies to increase or to decrease responsiveness to the stimuli are

superimposed on the conditioning tendencies. The values in Table 2 are the behavioral resultants of the various tendencies affecting the responses.

Adjustments should perhaps have been made from the uncorrected raw scores to compensate for the lack of adequate matching of the groups on Day 1, the session within which all subjects were treated alike. While the values obviously lack precision, they suffice for the preliminary comparisons which it is designed to make in this paper.[3] The values were determined in each case from 60 records from each of 10 subjects, providing a total of 600 records on which to base each percentage.

Accepting the obtained values, the problem is to arrange equations relating the symbols of Table 1 to the empirically determined values of Table 2. These equations, when solved, will furnish measures of the inferred tendencies symbolized in Table 1. It is necessary to make assumptions regarding the interaction of the tendencies before the equations can be written.

The simplest assumption is that responses as observed in the experiment appear at a frequency determined by the algebraic sum of the tendencies effective. That is to say, a positive tendency to react 50 per cent of the time, added to a negative tendency of − 20 per cent, would yield overt responses in 30 per cent of the trials. It might be possible, therefore, to use percentage of response directly to infer the strength of underlying tendencies. There is a serious objection to this, however, for percentage increases and decreases are not equivalent at different levels of mastery. It takes many more reinforcements, for example, to increase simple conditioned responses from 60 per cent to 70 per cent than it does to increase them from 30 per cent to 40 per cent. The assumption of algebraic summation will be more satisfactory if some method of scaling is adopted whereby fre-

[3] Calculations (not presented) have been made on the basis of experimental values adjusted to compensate for Day 1 inequalities. This introduces further assumptions without contributing substantially to the analysis. The quantitative values are altered, but the methodological argument is little affected. Other aspects of the data (amplitude, latency) could also be used in a more elaborate analysis.

quency in per cent is changed to a scale with units more nearly equal.

Since interest centers primarily in increases and decreases of conditioned responses, the curve of acquisition of simple conditioned responses as a function of reinforcement may serve as a basis for scaling. A scale may be constructed which represents percentage increases in terms of the number of reinforcements required to bring them about. Other tendencies may then be referred to this scale, and expressed as equivalent to the addition (or subtraction) of reinforcements.

Data are available for increases in the frequency of conditioning with reinforcement for 63 college students tested on two successive days.[4] This is the group designated as Group S in Table 2. The curve of acquisition is reproduced in Fig. 1. The unbroken smooth curve is one of best fit, calculated

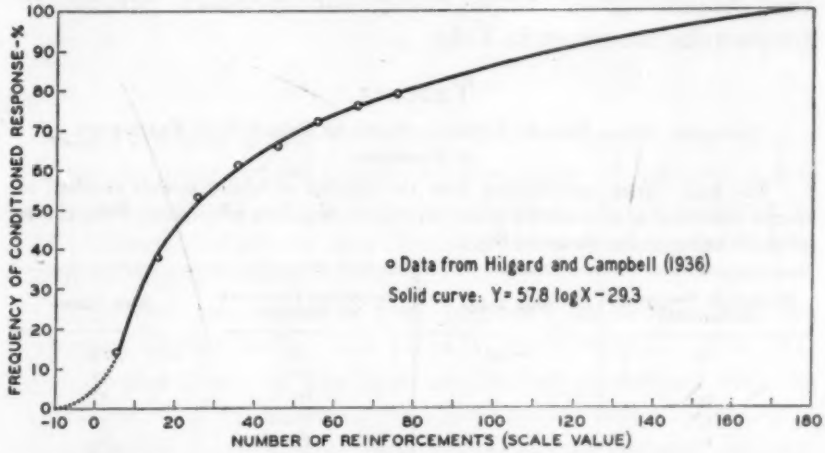

FIG. 1. Curve of acquisition of simple conditioned eyelid responses as a basis for scaling. The small circles represent average percentage frequencies from 630 records each (10 from each of 63 subjects). The data are from Hilgard and Campbell (3). The solid line was fitted by the method of least squares, and values extrapolated according to the equation indicated in the body of the figure. The positively accelerated initial portion of the curve is broken to indicate that it is drawn without reference to the equation of best fit, on the basis of other information available with respect to the early portion of the curve (4). The number of reinforcements required to reach a given percentage frequency is accepted as the scale value corresponding to that frequency. Specimen values are given in Table 3.

[4] The values were obtained from unpublished portions of the data from Hilgard and Campbell (3).

by the method of least squares to have the equation $y = 57.8 \log x - 29.3$, where y is per cent of conditioned responses, and x is number of reinforcements. The small circles are the obtained data.

The lower portion of the curve (dotted) is inferred from the well-known fact of initial positive acceleration, previously shown to hold within these data (4). Since the curve is to be used only as a basis for scaling, it does not matter that the equation chosen is one for which the parameters do not have rational significance.

In deriving a scale from the curve of best fit, the principle followed is that percentage frequencies of response shall be expressed in a scale corresponding to the number of reinforcements. The curve of acquisition, plotted in such units, will be a straight line, within the limits of the fit of the data to the chosen curve. Scale values for specimen percentage frequencies are given in Table 3.

TABLE 3

SPECIMEN SCALE VALUES CORRESPONDING TO PERCENTAGE FREQUENCY OF RESPONSE

The scale values are obtained from the number of reinforcements required in simple conditioning to reach the given percentage frequency of response if the course of conditioning is that shown in Fig. 1.

Percentage Frequency of Response	Scale Value	Percentage Frequency of Response	Scale Value
0	−10	55	29
5	0	60	35
10	4	65	43
15	6	70	52
20	7	75	64
25	9	80	78
30	11	85	95
35	13	90	116
40	16	95	141
45	19	100	173
50	24		

The obtained values of Table 2 are expressed as scale values in Table 4. It is assumed that these scale values may be added and subtracted algebraically in the determination of the response tendencies. This assumption will be referred to as Assumption 1.

4. Equations for Algebraic Treatment

The logical procedure for algebraic treatment to secure values for the tendencies inferred to affect response is straightforward. The problem is simply to arrange equations relating the symbols of Table 1 to the responses expressed in the scale values of Table 4. When the equations are solved, the

Table 4

Obtained Frequencies Converted to Scale Values

	Obtained Percentage Frequencies from Table 2, Days 2 and 3		Scale Values, Days 2 and 3	
	Positive Stimulus	Negative Stimulus	Positive Stimulus	Negative Stimulus
Group S	80	None	78	None
Group A	75	37	64	14
Group B	74	26	61	9
Group C	90	13	116	5
Group D	71	94	54	136
Group E	55	19	29	7

various tendencies will be expressed in the scale units, that is to say, in units proportional to the number of reinforcements required to bring about the same effect. The importance of the different influences may therefore be judged by a common scale of measurement.

The first assumption, that response tendencies may be summed algebraically, has already been stated. How this assumption leads to the construction of equations may be illustrated by considering the tendencies effective in discriminatory conditioning under usual circumstances, without supplementary voluntary instructions. The following equations may be assumed to hold:

Frequency of obtained responses to positive stimulus $(C_p + C_n')$

Frequency of obtained responses to negative stimulus $(C_p' + C_n)$ (Illustrations of Assumption 1)

These equations mean that two tendencies affect the responses to each stimulus, one positive and one negative.

The positive stimulus is reacted to in accordance with the effects of reinforcement (C_p) but response is inhibited somewhat by a generalized tendency (C_n') arising from the non-reinforced negative stimulus. Similarly, the negative stimulus is reacted to in accordance with a generalized positive tendency (C_p') diminished by the negative tendency (C_n) arising from non-reinforcement.

In accordance with this first assumption, equations have been written for each of the experimental conditions, with the algebraic sum of the tendencies set equal to the scale value of the measured behavior. These equations are given in Table 5. Their solution, and the interpretation of the values which result, are the primary tasks of this paper.

In order to arrive at determinate values for the tendencies listed in the equations of Table 5, it is necessary to make an assumption regarding the amount of generalization from one stimulus to the other. Since we have used only one pair of stimuli, it is not possible to make use of the analysis of generalization made so neatly by Spence (17). A fairly plausible assumption is that, for a given pair of stimuli, generalization is proportional to the size of the reaction tendency. That is to say, if a positive tendency of scale value of 30 should yield a generalized tendency of scale value 15 in respect to the other stimulus, then one of 40 may be supposed to result in a generalized tendency of 20. Other alternatives are possible, such as a direct generalization in a given amount, not proportional to the strength of the tendency. No evidence is directly available from within the experiments under consideration to force a choice, and the arbitrariness of the assumption must not be overlooked. Since it is being assumed that both positive and negative tendencies are generalized proportionate to their strengths, the following relationships express the assumption mathematically:

$$\frac{C_p'}{C_p} = \frac{C_n'}{C_n} \quad \text{and} \quad \frac{V_p'}{V_p} = \frac{V_n'}{V_n} \qquad \text{(Assumption 2)}$$

On the basis of these assumptions, it is possible to make two determinations of most of the tendencies involved in the

equations of Table 5. When different determinations disagree, either the measurements are in error, or the assumptions are faulty. When the values are reasonably close together, errors of measurement may be permitted to account for them, but when values depart too widely, the assumptions will be questioned.

5. Effect of Introducing the Negative Stimulus

After a period of simple conditioning, in which one stimulus is regularly presented followed by reinforcement, the introduction of a second stimulus, not reinforced, may result not only in the giving of conditioned responses to the second stimulus, but also in the reduction in responses to the original positive stimulus. The problem is to determine the magnitude of such changes as represented within the equations of Table 5.

TABLE 5

EQUATIONS EXPRESSING RELATIONSHIP BETWEEN INFERRED TENDENCIES AND RESULTING SCALE VALUE OF RESPONSES IN EACH OF THE GROUPS

	Responses to Positive Stimulus			Responses to Negative Stimulus		
	Tendencies Present	Scale Value	Equation No.	Tendencies Present	Scale Value	Equation No.
Group S. Simple conditioning	(C_p)	= 78	(1)	(None)		
Group A. No added instructions	(C_p+C_n')	= 64	(2)	$(C_p'+C_n)$	= 14	(7)
Group B. Information about stimuli	(C_p+C_n')	= 61	(3)	$(C_p'+C_n)$	= 9	(8)
Group C. Instructed to respond to positive, not negative	$(C_p+C_n')+(V_p+V_n')$	=116	(4)	$(C_p'+C_n)+(V_p'+V_n)$	= 5	(9)
Group D. Instructed to respond to negative, not positive	$(C_p+C_n')+(V_p'+V_n)$	= 54	(5)	$(C_p'+C_n)+(V_p+V_n')$	=136	(10)
Group E. Instructed to refrain from response to both	$(C_p+C_n')+(V_n+V_n')$	= 29	(6)	$(C_p'+C_n)+(V_n+V_n')$	= 7	(11)

The value for the strength of the tendency C_n' which reduces response to the positive stimulus may be determined from Equations (1) and (2) and also from (1) and (3).

From Equations (1) and (2), $C_n' = (2) - (1) = 64 - 78 = -14$. I

From Equations (1) and (3), $C_n' = (3) - (1) = 61 - 78 = -17$. II

These values should not agree precisely, for there was a difference in instructions between Group A and Group B, not accounted for in the equations. The following conclusion may be stated:

> *Conclusion 1.*—Introducing a negative stimulus following simple conditioning decreases the frequency of conditioned responses to the positive stimulus. Two determinations yielded values of − 14 and − 17 for the scale value of the negative tendency.

Determination of the amount of generalization of the positive tendency (C_p') and the strength of the negative tendency (C_n) requires a somewhat more complicated calculation, involving Assumption 2. The values may be determined from equations (1), (2), and (7), and independently from equations (1), (3), and (8). The steps of the first calculation will be indicated. The second is similar, but uses different values.

From assumption 2, it is evident that $C_p'C_n = C_pC_n'$.

Substituting the values for $C_p = +78$ (Equation 1) and $C_n' = -14$ (from I, above), we have

$$C_p'C_n = 78(-14) = -1092.$$

From Equation (7), $C_p' + C_n = 14$, and $C_n = 14 - C_p'$. Therefore,

$$C_p'(14 - C_p') = -1092, \text{ and } C_p'^2 - 14\,C_p' = 1092.$$

The following values result when the quadratic is solved:

$$C_p' = +40.8 \qquad \text{III}$$

$$C_n = 14 - 40.8 = -26.8 \qquad \text{IV}$$

Similar calculations based on Equations (1), (3) and (8) yield the following values:

$$C_p' = +41.2 \qquad \text{V}$$

$$C_n = -32.2 \qquad \text{VI}$$

Reduced responsiveness to the negative stimulus may be interpreted either as a failure of generalization, or as an active

inhibitory process. While ordinarily the choice of interpretations is to some extent a matter of taste, once assumptions are stated, and determinations made, interpretations are restricted. Both determinations of C_p' indicate that generalization is incomplete, and that part of the lack of responsiveness to the negative stimulus must be interpreted on these grounds. It is true that assumption 2 contributes importantly to these calculations, but unless the assumption is questioned, the inference follows.

> *Conclusion 2.*—Reduced responsiveness to the negative stimulus depends both on incomplete generalization of the positive tendency, and upon a negative tendency generated by non-reinforcement. The values from two determinations are: for the generalized positive tendency C_p', $+40.8$ and $+41.2$, for the negative conditioned tendency C_n, -26.8 and -32.2.

6. Effect of Information About the Stimuli

It will be recalled that Groups A and B, whose results were used in securing the values above, were treated differently, but these differences were not represented in the equations. Their effects should show, therefore, in the values of the conditioning tendencies. The subjects of Group A were given no advance information about the stimuli, while those of Group B were informed that the negative stimulus was to be introduced. Evidence previously reported showed clearly that information about the stimuli aided the initial discrimination by the subjects of Group B (**6**). If we accept the algebraic results, we may locate the change introduced by the information. Knowledge that the negative stimulus was to be introduced without reinforcement might have had the effect either of reducing the generalization from the positive tendency, or of strengthening the negative tendency. According to the determined values, the information resulted in a slight average increase in the strength of negative tendencies from -26.8 in Group A to -32.2 in Group B. The effect, as spread over two days of experimentation, should not be great. Responses to the positive

stimulus were correspondingly reduced by the generalization of this negative tendency, C_n' being -14 for Group A and -17 for Group B. According to the calculations there is no change in the generalization of the positive tendencies, the value for C_p' being $+40.8$ for Group A and $+41.2$ for Group B. Since the advance information about the stimuli possessed by Group B was available to the subjects of Groups C, D, and E, further comparisons will use values derived from Group B rather than those from Group A.

Conclusion 3.—Information about the stimuli in advance of the introduction of the negative stimulus may increase the strength of negative tendencies. For Group A, without information, the values are: C_n, -26.8; C_n', -14; for Group B, with information: C_n, -32.2; C_n', -17.

7. Effect of Voluntary Supplementation

The effect of voluntary supplementation of response may be studied by examining the reactions to the positive stimulus by Group C and to the negative stimulus by Group D. Two determinations of the value of $(V_p + V_n')$ are possible.

From Equations (3) and (4), $(V_p + V_n') = 116 - 61 = +55$.

From Equations (8) and (10), $(V_p + V_n') = 136 - 9 = +127$.

These values depart too widely from each other to be accounted for on the basis of errors of measurement, and therefore the assumptions on which they are based must be criticized. The main assumption is that the voluntary tendencies summate with conditioned tendencies. If this assumption were correct, one could expect a greater frequency of response to the positive stimulus of Group C than to the negative stimulus of Group D. The reverse is true. This suggests that the positive voluntary response has the right of way, and is relatively independent of the conditioned tendencies which it supplements. This suggestion is borne out by the nature of the voluntary responses as reported (7).

They are of lower latency and of greater amplitude than the conditioned responses. While the voluntary tendencies undoubtedly influence the conditioned response tendencies, when voluntary responses occur the measure secured from the records is one of voluntary responses, and not a measure of conditioned responses. Voluntary tendencies do not in fact interact with conditioned tendencies in the simple fashion represented by the equations of Table 3.

The assumption of algebraic summation introduces most error in the case of addition of positive voluntary tendencies to strong positive conditioned tendencies because in such cases one tendency may simply conceal the other. This corresponds to occlusion as described in reflex physiology. Where both tendencies are relatively weak the sum of both will result in a frequency of response greater than that from either alone, so that the assumption of summation introduces less error. When negative voluntary tendencies are present, reduction in both voluntary and conditioned responses may occur, so that here also direct interaction is evident from the records, and the assumption of algebraic summation, while not strictly appropriate, is not grossly misleading. As a makeshift correction of the faulty assumption of algebraic summation, direct voluntary positive tendencies will be assumed independent of conditioned tendencies. The assumption of algebraic interaction will be continued for generalized positive voluntary tendencies and for the negative voluntary tendencies. If the present crude analysis demonstrates the usefulness of a mathematical approach to the problems under consideration, subsequent refinements may be introduced based on corrected principles of interaction and using more valid measures.

In order to determine the values of V_p, V_p', V_n, and V_n', it is necessary to set up a series of equations for simultaneous solution. The tendencies in Group C, in which voluntary effort supported conditioned discrimination, will be calculated separately from those in Group D, in which voluntary effort was antagonistic to discrimination.

It is necessary to use the results from Group E to deter-

mine the values for the tendencies within Groups C and D. In Group E the negative voluntary tendencies were uncomplicated by positive voluntary tendencies.

From Equations (3) and (6), $(V_n + V_n') = -32$
From Equations (8) and (11), $(V_n + V_n') = -2$
Mean value $= -17.0$ (*a*)

Although these values disagree to an unsatisfactory extent, and the second (-2) is undoubtedly too small, it is significant that even the greater value (-32), representing a sum of direct and generalized tendencies, is small compared with either positive or negative conditioned tendencies. The mean value (-17) will be adopted for methodological purposes.

Conclusion 4.—While voluntary restraint may reduce the frequency of conditioned responses, the amount of reduction is small. The scale values of negative voluntary tendencies $(V_n + V_n')$ are -32 and -2 by two determinations.

With the figure for the sum of the negative voluntary tendencies as determined from Group E, the tendencies within Group C may be evaluated by solving the following equations:

From Equation (4), $(V_p + V_n') = +116$ (Assuming that voluntary tendencies account for the responses as measured.)
From Equations (8) and (9), $(V_p' + V_n) = -4$
From (*a*), above, $(V_n + V_n') = -17$
By Assumption 2, $(V_p'V_n) = (V_pV_n')$

Simultaneous solution of these four equations yields the values:

$V_p = +117.5.$ VII
$V_p' = +11.5.$ VIII
$V_n = -15.5.$ IX
$V_n' = -1.5.$ X

These values satisfy the equations for Group C. The corresponding equations from which may be derived values for Group D, in which the voluntary tendencies were antagonistic to conditioning tendencies, are:

From equation (10), $(V_p + V_n') = +136$ (Assuming that voluntary tendencies account for the responses as measured.)
From equations (3) and (5), $(V_p' + V_n) = -7$
From (*a*) based on Group E, $(V_n + V_n') = -17$

By assumption 2, $(V_p'V_n) = (V_pV_n')$
The values which satisfy these equations are:

$V_p = +137.0.$ XI
$V_p' = +9.0.$ XII
$V_n = -16.0.$ XIII
$V_n' = -1.0.$ XIV

It is evident that positive voluntary tendencies are very potent in the determination of reactions in these experiments.

Conclusion 5.—Positive voluntary reponse tendencies reach the highest scale values of any of the tendencies inferred to be effective in these experiments. The scale value of V_p as determined for Group C is + 117.5, for Group D, + 137.

Although the positive voluntary tendencies are greater than the positive conditioned tendencies, the generalized conditioned positive tendencies are greater than the corresponding voluntary tendencies. This points to a difference in specificity of conditioned and voluntary reactions. The extent of generalization may be expressed as ratios.

From III and Equation (1), $C_p'/C_p = 40.8/78 = 0.52$.
From V and Equation (1), $C_p'/C_p = 41.2/78 = 0.53$.
Mean value = 0.53 (Ratio of generalization for conditioned tendencies).
From VIII and VII, $V_p'/V_p = 11.5/117.5 = 0.10$.

From XII and XI, $V_p'/V_p = 19/137 = 0.07$.

Mean value = 0.09 (Ratio of generalization for voluntary tendencies).

Voluntary tendencies are determined by specific instructions, whereas conditioning tendencies are the consequence of gross adjustments to reinforcement and non-reinforcement. The calculations agree with expectations.

Conclusion 6.—Tendencies produced by instructions to react voluntarily are generalized less than conditioned tendencies. The mean ratios of generalization are 0.53 for conditioned tendencies and 0.09 for voluntary tendencies.

8. Summary of the Algebraic Determinations

A series of values have been calculated for the component tendencies inferred to be affecting responses. By collecting these determinations, securing average values, and substituting in the equations, a systematized set of calculated values may be arranged for comparison with the response frequencies as obtained experimentally. The values assigned the different tendencies are summarized in Table 6.

Table 6

Summary of Scale Values of Different Inferred Tendencies as Algebraically Determined

Tendency	Symbol	Source of Values	Scale Values Derived from Separate Determinations	Adopted Scale Value
Conditioned positive	C_p	Equation 1	+78	+ 78
Generalized conditioned positive	C_p'	III, V	+ 40.8,* +41.2	+ 41
Conditioned negative	C_n	IV, VI	− 26.8,* −32.2	− 32
Generalized conditioned negative	C_n'	I, II	− 14,* −17	− 17
Voluntary positive	V_p	VII, XI	+117.5, +137.0	+127
Generalized voluntary positive	V_p'	VIII, XII	+ 11.5, +9.0	+ 10
Voluntary negative	V_n	IX, XIII	− 15.5, −16.0	− 16
Generalized voluntary negative	V_n'	X, XIV	− 1.5, −1.0	− 1

* The values derived from Group A are not averaged with those from Group B in determining the adopted scale value because the subjects of Group A lacked the information about the stimuli which was common to Groups B, C, D, and E.

In Table 7 are listed the results obtained when the values from Table 6 are substituted in the equations of Table 5.

The experimentally obtained values are listed for comparison. The arithmetical agreement for Groups S and B is of little theoretical importance, because these values are exact results of the solution of equations into which the obtained values enter. All of the other values have a greater degree of interdependence, and the extent of agreement is a crude measure of the possible validity of the assumptions. The chief disagreement is found within the values for Group E. The disparity between obtained and experimental values cannot be explained without new data and supplementary assumptions.

TABLE 7

AGREEMENT AND DISAGREEMENT BETWEEN RESPONSE FREQUENCIES AS OBTAINED EXPERIMENTALLY AND AS DETERMINED FROM CALCULATED VALUES OF INFERRED TENDENCIES

	Scale Values				Percentage Frequency of Response			
	Positive Stimulus		Negative Stimulus		Positive Stimulus		Negative Stimulus	
	Obtained	Calculated	Obtained	Calculated	Obtained	Calculated	Obtained	Calculated
Group S	78	78	—	—	80	80	—	—
Group B	61	61	9	9	74	74	26	26
Group C	116	126	5	3	90	92	13	9
Group D	54	55	136	126	71	71	94	92
Group E	29	44	7	−8	55	65*	19	1*

* These two values depart widely from the obtained ones. For discussion see text.

9. LIMITATIONS

The attempt has been made to apply algebraic analysis to a situation in which response changes occurred under a variety of instructed sets. As such the attempt is not new. An early illustration is furnished by the subtractive procedure as applied to reaction-time measurements in the hope of determining the speed of thought (11, pp. 472–3). Its failure is not to be considered as discouraging. On the contrary, the application of mathematics led to the rejection of the presuppositions being tested, and such rejection of faulty hypotheses is a mark of scientific advancement. A second

illustration is provided by the work of Ach (1), who attempted to measure will in opposition to associative habit in retention experiments. There is a close analogy between his experiments and those reported here. Ach made the error of too rigid an oversimplification, however, so that the methodological possibilities of the algebraic approach were not exhausted.[5]

The analysis which has been presented suffers from a number of limitations, which conceivably could be overcome by improvement of data, refinement of assumptions, and re-examination of inferred tendencies. The first assumption, of algebraic summation, does not apply strictly, and requires modification. The second, with regard to the extent of generalization, should be revised on the basis of empirical data, and should be supplemented as necessary to allow for contrast effects (including what Pavlov called positive and negative induction). The interdependence of voluntary and conditioned tendencies should be reformulated on the basis of appropriate experiments similar to those of Peak (15) and Miller and Cole (14).

Even with supplementary data and more valid assumptions, the analysis depends ultimately on the tendencies inferred to be affecting responses. If these are well chosen their determination will prove to be of value in new contexts. If they are badly chosen, algebraic manipulation alone may not reveal their weaknesses. There is an illusory finality to equations which make predictions in a limited setting.[6]

As an illustration of a possible omission in the list of inferred tendencies, consider the suggestion that simple conditioned responses develop against an opposing negative tendency, which is neglected in the analysis. If this suggestion is true, the low values found for negative tendencies may be accounted for, since the tendencies as measured and inferred are merely the increments added by instructions or

[5] Ach's work has been criticized by Lewin (12) and Schwarz (16), who offer alternatives.

[6] For an emphasis on the desirability of rational formulations in contrast to purely empirical descriptions see, for example, Crozier and Hoagland (2).

non-reinforcement to the ignored negative tendency already present. If such a negative tendency is inferred in simple conditioning, every equation in Table 5 is altered, *without modifying the agreement between observed and calculated values.* The probability is great that simple conditioned tendencies do actually develop against opposing tendencies. This has been emphasized by Liddell and his coworkers (**13**), who point out the importance in animal experiments of the original trained negativism. Subjects in our experiments were instructed to fixate visually. This instruction to keep the eyes open conflicts with the conditioning tendency, and perhaps accounts for the gradualness with which simple conditioned responses appear. It may also account for the rapidity of extinction, for during non-reinforcement the tendency to keep the eyes open as a result of instructions wins out in its conflict with the conditioned tendency to close the eyes.

Since the crux of the matter appears to lie in the choice of the inferred tendencies, a choice not dictated by the algebraic analysis, the mathematical approach seems to be secondary to a situational study and interpretation. This is indeed the case, but the mathematical approach is not thereby discredited. The virtue of a quantitative mathematical treatment is that alternative suggestions lead to definite consequences which may be tested. Thus one consequence which would follow inevitably from the acceptance of a negative tendency in simple conditioning, as described above, would be to increase the relative size of negative tendencies. This is a plausible consequence, since the values of negative tendencies, particularly negative voluntary tendencies, as determined through the original analysis, appeared to be unreasonably low.

10. Deductive Fertility

Hull (**10**) has been campaigning very usefully for analyses which make precise deductions leading to experimental confirmation or denial. The present analysis may be tested for such fertility. While certain deductions going beyond the restricted universe of the experiments might be made (relative

to the influence of repetitive performance and verbal instructions as response determiners), it appears to be more fruitful at the present stage to confine deductions to the 'miniature system' represented by discriminatory eyelid reactions.

One set of deductions follows directly from the series of variables to which values have been assigned in Table 6. It is evident that many new equations can be written, combining the variables in new ways. It is then possible to perform the experiments which these equations symbolize, either to test the values previously arrived at, or to secure a basis for their revision. As more combinations are secured, the values will become more determinate, and fewer arbitrary assumptions will be needed. A specimen series of further possible groups is given in Table 8, with the values as predicted from present assumptions and determinations.

The arrangement of Group F provides an opportunity to study the generalization of positive conditioned tendencies uncomplicated by negative ones.[7] The method could be used as a test of equivalence of stimuli. The more nearly equivalent the stimuli, the more C_p' should approach the value of C_p. The reason 0.5 C_p is assigned as the value for the positive conditioned tendency in respect to the 'negative' stimulus is that by the end of Day 3 it will have received half the reinforcements given the positive stimulus. The adopted method of scaling makes the positive tendency proportional to the number of reinforcements.

Groups G and H, involving supplementary voluntary instructions, provide further tests of the assumptions regarding the interaction of voluntary and conditioned tendencies.

Groups I and J are designed to test voluntary reactions under the circumstances of the experiments uncomplicated by conditioning.

The deductive fertility of the algebraic approach is not limited to setting up equations of this sort and securing agreements with earlier determinations. Just as important a function is served in calling attention to disagreements, and thereby directing attention to types of experiment needed to

[7] Unless the presence of a negative tendency in simple conditioning is accepted.

clear up internal inconsistencies within the data. In the course of discussion it has been suggested that the interaction of voluntary and conditioned tendencies requires detailed study, that simple conditioning deserves consideration as a conflict situation, that extinction is probably not a simple

TABLE 8

RECOMBINATIONS OF INFERRED TENDENCIES AS A TEST OF CALCULATED VALUES AND OF ASSUMPTIONS REGARDING SUMMATION

The groups are hypothetical and the experiments have not been performed

	Tendencies Determining Responses to Positive Stimulus (Days 2 and 3)			Tendencies Determining Responses to Negative Stimulus (Days 2 and 3)		
	Tendencies	Scale Value (Calculated)	Predicted Percentage Frequency	Tendencies	Scale Value (Calculated)	Predicted Percentage Frequency
Group F. Simple conditioning to positive stimulus on Day 1. Both stimuli reinforced on Days 2 and 3. No added instructions	$(C_p+.5\ C_p')$	=+ 99	86	$(.5\ C_p+C_p')$	=+ 80	81
Group G. Simple conditioning to positive stimulus on Day 1. Both stimuli reinforced on Days 2 and 3. Instructed to respond to positive, not to negative	$(C_p+.5\ C_p')+(V_p+V_n')$	=+126	92	$(.5\ C_p+C_p')+(V_p'+V_n)$	=+ 74	79
Group H. Simple conditioning to positive stimulus on Day 1. Both stimuli reinforced on Days 2 and 3. Instructed to refrain from responding to either	$(C_p+.5\ C_p')+(V_n+V_n')$	=+ 82	81	$(.5\ C_p+C_p')+(V_n+V_n')$	=+ 63	75
Group I. Day 1 omitted. Neither stimulus reinforced. Instructed to respond to positive, not to negative	(V_p+V_n')	=+126	92	$(V_p'+V_n)$	=− 6	2
Group J. Day 1 omitted. Neither stimulus reinforced. Instructed to respond to both	(V_p+V_p')	=+137	94	(V_p+V_p')	=+137	94

obverse of acquisition, that incomplete generalization cannot be distinguished satisfactorily from negative tendencies until more evidence is obtained regarding quantitative aspects of generalization. While many similar observations might be made by anyone familiar with conditioning experiments,

attempted algebraic treatment demands that some kind of quantitative disposal be made of such problems.

After the 'miniature system' is in order it will be important to know to what extent it can be generalized to other situations. If it is ever to be a science deserving of the name, psychology must become both rational and quantitative. It can only do so by making inferences and substantiating them with data. Numerous 'miniature systems' more completely worked out with their inferred tendencies, assumptions, and verified predictions, should speed the process of finding better concepts for handling the more general problems of psychology.

11. Summary

1. Data from conditioned discrimination experiments complicated by voluntary support and antagonism were treated algebraically in order to arrive at quantitative values of the tendencies inferred to be affecting response.

2. Eight tendencies were inferred to be effective. Of these four were conditioned tendencies: the positive tendency due to reinforcement of the positive stimulus, its generalization to the negative stimulus, the negative tendency due to non-reinforcement of the negative stimulus, and its generalization reducing responses to the positive stimulus. The remaining were voluntary tendencies, positive and negative depending on instructions, and their generalizations to the other stimulus. The tendencies were inferred from behavior, without physiological implications.

3. By making assumptions regarding the scaling of values, algebraic summation, and generalization, it was possible to arrange 11 equations expressing the inter-relationships of the variables in experiments conducted with 6 groups under different instructions. Two separate solutions were possible for most of the variables. Where determinations disagreed, the results could be attributed either to experimental errors, faulty assumptions, or both. With assumptions modified in cases where disagreement was too great, values were obtained

from which could be calculated rough approximations to the observed data.

4. Six conclusions were stated as arising out of the quantitative values as determined:

(1) Introducing a negative stimulus following simple conditioning decreases the frequency of conditioned responses to the positive stimulus.

(2) Reduced responsiveness to the negative stimulus depends both on incomplete generalization of the positive tendency and upon a negative tendency produced by non-reinforcement.

(3) Information about the stimuli in advance of the introduction of the negative stimulus may increase the strength of the negative tendencies.

(4) While voluntary restraint may reduce the frequency of conditioned responses, the amount of reduction is small.

(5) Positive voluntary response tendencies reach the highest scale value of any of the tendencies inferred to be effective in these experiments.

(6) Tendencies produced by instructions to react voluntarily are generalized less than conditioned tendencies.

These conclusions follow strictly, provided the data and assumptions are accepted as valid.

5. Limitations of the procedure are discussed. Three aids to overcoming the limitations are indicated: improvement of data, refinement of assumptions, and re-examination of inferred tendencies.

6. The deductive fertility of the algebraic method is also examined. Five new experimental arrangements are suggested which combine the variables as a test both of the quantitative values and of the underlying assumptions. Predicted results from these experiments are calculated from the quantitative determinations. The desirability of 'miniature systems' which are both rational and quantitative is indicated.

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THE CONCEPT OF TRAITS

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The concept of traits is of popular origin, but it has been introduced into the field of psychology only in recent years. In our daily activities we have developed a multitude of trait names to denote the various characteristics of individuals. While we have a practical knowledge of the meaning of these various terms, yet we may be unable to give any analytical and systematic definition of the concept. Such a definition, however, is essential if the concept is to be used as one of the major categories of psychology. This paper attempts such an analysis, and we shall first define the concept in general and abstract terms, and then proceed to illustrate and amplify these definitive statements in the succeeding topics.

Definition.—A trait is a conceptual attribute or definition of the reactive nature of an individual. The nature of the individual is defined on the basis of certain observable behavior characteristics. Not all observable characteristics are used for this purpose. The definition is based only upon those characteristics (1) which society regards as of sufficient importance to identify and name, and (2) which are regarded as expressions or manifestations of the constitutional nature of the individual. The term 'constitutional nature' refers to all of those relatively permanent and enduring organic conditions that characterize a given individual and differentiate him from his fellows, and these organic conditions may be both innate and acquired in respect to origin.

As an illustration, we observe that a given individual acts aggressively and persistently in his endeavors. We also judge that these two modes of conduct are of some significance in accounting for the success of his endeavors. Let us also assume that we have observed these two modes of conduct under such a variety of circumstances that we are forced to

conclude that they are expressions or manifestations of his constitutional nature—that the individual acts in these specified ways because he is made that way. Under these conditions, we define this person as an individual who acts persistently and aggressively, or as a persistent and aggressive individual.

In this typical illustration, we observed certain *adverbial* characteristics of the individual's behavior. He acted persistently and aggressively. In defining the reactive nature of the individual, we use *adjectival* terms. He is a persistent and aggressive individual. When we regard these attributes as objects of thought abstracted from the individuals to whom they belong, they become *nouns*, and we refer to them as persistence and aggressiveness.

The observed modes of conduct are judged to be functions of the constitutional nature of the individual, and the nature and locus of these organic conditions will presumably vary with the trait. Since the nature and locus of these conditions for any trait are unknown, we cannot refer to them directly, and hence we are forced to define the individual in virtue of his possession of them. Since these organic conditions corresponding to each observed mode of behavior are constitutional in character, *i.e.*, relatively permanent and enduring, we can reasonably expect this individual to continue acting in these ways in the future. In other words, our individual is defined as that type of person who not only has acted in these ways in times past but who may be reasonably expected to act in the same ways in the future. The concept of traits thus has a three-fold meaning reference. 1. It is based upon and hence refers to observed modes of behavior. 2. It is an attribute or definition of the reactive nature of an individual. 3. It has a predictive reference in that it defines the individual in terms of his future modes of behavior.

Observational sources.—An individual exhibits a multitude of traits, and our knowledge of these traits is derived from a number of observational sources.

1. *Manner of acting.*—We are here dealing with the adverbial characteristics of our overt reactions in reference to

objects. Every act exhibits a great variety of adverbial characteristics, and many traits find their origin in these characteristics.

The previously cited traits of persistence and aggressiveness are examples of this type of origin. Likewise, an individual may be characterized as affable, assertive, adventurous, candid, cordial, courteous, cooperative, deliberative, domineering, exuberant, evasive, generous, gracious, industrious, impulsive, loyal, loquacious, modest, punctual, pugnacious, petulant, reticent, shrewd, silly, temperamental, tactful, unctuous, vacillating, and vindictive.

2. *Reactions to objects.*—This topic refers to an individual's *reactions to objects* as distinct from his *actions in reference to objects*. An individual's actions always occur in a spatial environment. An individual reacts to all of these environmental objects, but he acts in reference to but one object or group of objects at a time. The object of reference is usually termed the goal object, and the nature of the act is specified in terms of this object of reference. An individual walks home to lunch, delivers a lecture, dodges an automobile, and hurries to catch a train. However, the character of our actions in reference to these goal objects is continually being influenced by these environmental objects in which the act occurs. We thus *react to* these environmental objects while *acting in reference* to the goal object.

In the previous section, we listed traits that are primarily based upon an individual's manner of acting in reference to objects. In this topic we are concerned with those traits that are primarily based upon an individual's modes of reacting to objects. An individual is hurrying to catch a train, and the speed and energy of his movements are materially influenced by the actions of his fellows in reference to the same objective. On the basis of such observable reactions, the individual may be defined as a suggestible person. An individual is emotionally disturbed by certain environmental distractions while performing a given task, and on this basis he may be characterized as an irritable or peevish person. In the pursuit of its own ends, a child may be wholly impervi-

ous to the suggestions, admonitions, and commands of its parents, and hence it may be labelled as a stubborn child.

As illustrations of this type of origin, individuals are characterized as apologetic, apprehensive, excitable, gullible, independent, irritable, impressionable, peevish, resistant, stubborn, sensitive, suggestible, shy, retiring, etc.

3. *Postural and expressive activities.*—The muscles of the body exhibit varying degrees of tonicity. They may be either tense and firm, or loose and flabby. The jaws may be set, and the brows contracted in a frown. With some individuals the pattern of these postural activities may be relatively stable and immobile in character. With other individuals the pattern keeps continually changing. The position of the arms and legs keeps shifting, the posture of the head and body is varied, the face is extremely mobile, and the eyes keep changing their expression.

The overt activity of an individual is always perceived against this background of postural and expressive activities. Our judgments of an individual's traits are usually based to some extent upon both components, but the relative influence of these components will vary with the trait. In the first section we listed a number of traits which are based primarily upon the characteristics of overt acts. In this section we are concerned with those traits that are primarily based upon the nature of these postural and expressive activities.

On this basis individuals are characterized as alert, animated, confident, dreamy, enthusiastic, effervescent, earnest, gloomy, haughty, humble, moody, morose, phlegmatic, proud, poker-faced, reserved, stupid, stolid, sullen, sober, self-reliant, and vivacious.

4. *Kind of action.*—We also define the nature of individuals on the basis of what they do. Individuals are so defined on the basis of various *unusual kinds* of behavior when these acts are regarded as expressions of the nature of those individuals. In this case the individuals are usually defined in terms of *nouns* instead of adjectives. On this basis individuals are labelled as liars, thieves, drunkards, panderers, loafers,

bums, bullies, bluffers, philanthropists, saints, patriots, and heroes.

5. *Class labels.*—It is customary to classify and label individuals on the basis of the various vocational, racial, social, and political groups to which they belong. Individuals are referred to as farmers, merchants, artisans, clerks, doctors, teachers, artists, Gentiles, Methodists, Republicans, Communists, Yankees, and Southerners. These class labels are used in three ways:

A. We may be merely interested in identifying a given individual in terms of some of these class distinctions, and we say that he is a banker, a Presbyterian, and a Republican of Scotch ancestry. Obviously these class labels are not traits when used in this way.

B. There is a popular assumption that the members of these groups are likely to have distinctive personality characteristics. There are two reasons for this assumption. The choice of a vocation may be due in part to the individual's personality characteristics—his abilities, desires, interests, attitudes and traits. Likewise, the distinctive characteristics of a banker, a physician, a teacher, and a farmer may be due in part to their respective vocational activities. For example, certain temperamental characteristics may in part be responsible for some cases of spinsterhood, and in turn certain personality characteristics may be the resultants of this mode of life.

We often wish to describe an individual in terms of his distinctive pattern of personality characteristics—his distinctive combination of traits, attitudes, interests and abilities, and we find it convenient to do so by labelling him in terms of those groups of which he is a typical member. We characterize him as a typical politician, a professor, a Communist, a standpat Republican, or as a breezy Westerner. The terms are here used to denote that combination of personality characteristics that are popularly supposed to be distinctive of those groups.

C. The nature of the individual is sometimes denoted by the label of a group to which he does not belong. The label

is applied in this case to call attention to some pattern of characteristics that is supposed to be typical of that group. For example, an individual is often called a Scotchman because of his reputation for canniness and thrift. These group labels are often used as epithets and applied to people whom we do not like. Such terms as bum, rube, politician, and Communist are often used in this way.

As we have noted, these group labels are used to denote certain combinations of personality characteristics which include abilities, interests, attitudes and ideals as well as traits. For this reason such terms cannot be regarded as legitimate trait names. We have referred to them in this connection merely for the purpose of sharply delimiting the concept of traits.

6. *Affective, emotional and conative reactions.*—In the previous sections, the reactive nature of an individual has been defined on the basis of certain observable characteristics of that individual's behavior. The nature of an individual can also be defined on the basis of the observer's modes of reaction to that individual. Many traits find their origin in the affective, emotional, and conative reactions of the observer to the individual. On this basis individuals are characterized as admirable, attractive, aggravating, charming, disgusting, depressing, horrid, hateful, irritating, interesting, intriguing, impressive, inspiring, likeable, lovable, pleasing, popular, repulsive, stimulating, soothing, satisfying, and terrifying, and many other examples might be given. The observational source of these traits is obvious.

These modes of reaction of the observer to an individual are usually aroused by a complex pattern of stimuli. Many of these stimuli consist of those behavior characteristics which are the basis of the various traits listed in the previous sections. I term an individual a likeable person on the basis of my observed mode of reacting to him. Let us suppose that I react to this individual in this manner because of the affable, courteous, gracious, enthusiastic and responsive characteristics of his overt and postural activities. I can now define this individual in an analytical fashion as an affable,

courteous, gracious, enthusiastic and responsive person, or I can define him as a likeable individual on the basis of my configurational reaction to him. Both methods of characterizing individuals are useful, and neither one is superfluous.

Some of the advantages of this type of characterization may be briefly noted. 1. We are often ignorant of the various features of an individual which combine to elicit a particular mode of reaction to him. We know that we dislike a certain individual, but are unable to give any adequate and satisfactory analysis of our reasons for so doing. In such cases we are forced to characterize the individual on the basis of his reactive effect upon us. 2. We often react to individuals on the basis of their anatomical as well as behavior characteristics. We may characterize an individual as a repulsive person largely because of a number of his anatomical features such as birth marks, skin defects, and peculiarities of facial conformation. An individual may be termed an impressive person because of his height, statuesque proportions, and rugged features, as well as of his manner of action. The reactive nature of an individual can be defined in terms of these anatomical features only in so far as these influence the reactions of other people to him. 3. The combination of qualities that arouse a given reaction in an observer will vary with the individual. I may like one individual because of one combination of qualities, and like another individual equally well because of some other combination of qualities. Trait characterizations based upon the observer's mode of reaction to individuals are thus the more general in their significance. 4. In practical life we are often interested in an individual from the standpoint of his effectiveness in dealing with other people. Naturally his effectiveness will be in large part a function of their affective, emotional and conative attitudes toward him, and consequently this class of traits is of prime importance for such purposes. 5. Likewise these reactions of an observer to an individual are often evoked by a particular pattern or combination of qualities, and this combination of circumstances can best be denoted in terms of the observer's unitary reaction to them.

As we have indicated, very few traits are based exclusively upon any one of the observational sources which we have listed. Our trait definitions represent our reactions to the individual as a whole, and they are usually based upon a variety of behavior characteristics. In our illustrations we merely cited those traits that are *primarily* based upon some one of these sources. Our analytical classification is an arbitrary one, and it has been introduced merely to depict the variety and complexity of these conditions.

Standards of reference.—As we have stated, our popular trait definitions of the reactive nature of an individual are based upon those observable characteristics of behavior which society deems of sufficient importance to identify and name. The concept of importance implies a standard of reference. A particular characteristic of behavior has no importance in and of itself. Its importance is a function of the degree to which it contributes to the success or failure of an individual in adjusting to some of the various conditions of life. Obviously there are a multitude of such standards of reference, and the nature of these may be briefly indicated.

Many modes of behavior are evaluated in relation to various vocational ends. We judge them in respect to their function in contributing to the success or failure of an individual as a potential farmer, mechanic, artist, salesman, physician or business executive. In a complex society the number of vocations is almost legion, and likewise a given vocation involves a great variety of distinctive behavior situations. Not only may the value of a trait vary with the vocation, but it may also vary with the behavior situation within a given vocation. For example, a given trait may distinctly contribute to the success of an individual as a trial lawyer, but be of no value for other types of legal situation. We may also note that the meaning or content of any trait term may vary with the vocation. For example, the honesty of a banker has quite a different connotation from that of the honesty of a scientific investigator. The great variety of concrete vocational situations in reference to which traits are evaluated is responsible for the large number of traits

which society has identified and named and for their diversities of meaning.

Every individual is necessarily a member of a number of small social groups, and his modes of conduct may be evaluated from the standpoint of his adjustment to these groups. Every individual is at least a member of a family and a neighborhood group, and an individual's modes of conduct can be evaluated in reference to his success as a husband, a father, and a neighbor.

Individuals are members of some political, economic, and cultural group unit, and their modes of behavior may be evaluated in reference to the continued welfare of this group. Such groups develop certain ideals and standards of conduct which they regard as essential to their stability and progress and to which they expect every member to conform. We are here dealing with such socially accepted traits and cardinal virtues as candor, honesty, integrity, loyalty, patriotism, sympathy, courtesy, industry, self-reliance, and 'rugged individualism.' Many of these general social traits may also be of value in meeting many vocational situations. Some traits may have the same value for a variety of purposes.

A social situation involves the interaction of at least two individuals. The two individuals may cooperate in the pursuit of a common end, or they may attempt to achieve diverse ends. In the latter case we can evaluate the behavior of one individual in reference to the attainment of his own ends, or in reference to the purposes of the other person. Since the value of a particular mode of conduct may differ according to the two points of view from which it is regarded, society sometimes finds it convenient to give two distinct labels to the same manner of acting according to the standard of evaluation. We have previously cited the apt illustration of a child who is wholly impervious to the commands and requests of its parents while in the pursuit of its own ends. Evaluated from the standpoint of the child's aims, this mode of conduct is termed persistence, and this is usually regarded as a socially desirable trait. When evaluated in reference

to the aims of the parents, this manner of acting is termed stubbornness, and it is usually regarded as an undesirable trait.

As we have stated, modes of behavior are utilized as a basis of trait definitions when they (1) are constitutionally conditioned and (2) possess some social importance. We now wish to call attention to the fact that there are many constitutional modes of behavior that are not so utilized because they lack the second characteristic of social importance.

The act of walking is an example. Individuals exhibit a variety of constitutional differences in manner of walking. An individual may walk easily, gracefully, lightly, mincingly, heavily, languidly, haltingly, vigorously, or waddle like a duck. The same thing is true of manner of talking. A person may talk hesitatingly, crisply, incisively, emphatically, nasally, sonorously, distinctly, precisely, monotonously, etc. Most of these distinctive ways of acting have not been used as a means of defining the reactive nature of individuals simply because society has not regarded them as of sufficient social importance, and for this reason their existence has tended to escape notice although they are readily observable when attention is once called to them.

We may also call attention to a class of behavior characteristics which are usually referred to as automatisms, mannerisms, and idiosyncracies of behavior. Krout [1] has recently compiled a list of 160 of such items as adjusting glasses, biting lips, brushing hands, cleaning nails, finger drumming, fixing hair, grinding teeth, picking nose, manipulating a finger ring, scratching head, shrugging shoulders, spitting, stroking mustache, and finger tapping. Some of these ways of behaving attract attention for esthetic and hygienic reasons. Others are noted for their distinctive character or frequent occurrence, but the great majority escape our notice until they are specifically called to our attention. They are not used as a means of defining the reactive character of indi-

[1] M. H. Krout, Autistic gestures, *Psychol. Monog.*, 1935, 46, pp. 22–26.

viduals because they are not usually regarded as sufficiently important for this purpose.

Constitutional basis.—According to our definition, the reactive nature of an individual is defined only on the basis of those modes of behavior that are judged to be expressions of his constitutional nature. Not all modes of behavior are constitutionally conditioned. In general the occurrence of a particular mode of behavior may be primarily due to any one of three sets of conditions.

1. An individual's manner of acting may be an intelligent adaptation to the behavior situation. An individual may put on a big front in order to impress a prospective employer. An individual who is gruff and discourteous by nature may be extremely courteous to someone whose favor he wishes to cultivate. An individual may simulate anger on occasion as a means of attaining his ends, and not because he is an irascible person. An individual cannot be adjudged a petulant and irritable person because he exhibits petulance and irritation only under extremely provocative circumstances. Modes of action that are obviously adapted to the exigencies of a situation and that are known to occur only under such circumstances cannot be regarded as an expression of the constitutional nature of the individual.

2. An individual's manner of acting may also be an expression of such temporary conditions as ill health, extreme fatigue, emotional disturbances, frustrated motives, etc. These temporary conditions will often affect an individual's postural and expressive activities, his manner of reacting to others, and the way these people react to him. We are not accustomed to define the reactive nature of an individual on the basis of such exceptional cases. A child that is known to be peevish and irritable only when it is sick is not usually characterized as a peevish and irritable person.

3. Finally these modes of action may be primarily expressions of the constitutional nature of the individual. An individual may act aggressively, courteously, impulsively, loquaciously, and be charming, haughty, or sullen in act and manner simply because he is built that way.

These constitutional conditions are both innate and acquired in respect to origin. The relative influence of these two factors presumably varies with the trait and the individual. Exuberance on the one hand and apathy on the other may be largely due to innate physiological conditions in the case of many individuals. Our judgments of the attractiveness and repulsiveness of some individuals may be largely based upon some of their outstanding anatomical characteristics. On the other hand, courtesy, cordiality, honesty, loyalty, and tact are usually regarded as acquired virtues that are expressions of deeply engrained habits of action.

It is often customary to limit the term 'constitutional' to innate types of condition. We wish to note that we are arbitrarily using the term to refer to both innate and acquired conditions. The term is here used to denote all relatively permanent and enduring conditions as contrasted with those fluctuating and temporary conditions described in the preceding section. Neither do these constitutional conditions necessarily remain fixed and unchangeable throughout life. They may exhibit marked change during childhood and adolescence due to the maturation of the organism, the specific training of home and school and the continual expansion of the child's environmental contacts. Traits remain more stable after maturity. Changes can and do occur during this period of life, but these changes must be regarded as the exception rather than the rule. For all periods of life trait characteristics change slowly and persist for relatively long periods of time.

Since a mode of action may be a function of any one of these three conditions, any valid judgment of the existence of a trait must be based upon the observation of this mode of behavior under such conditions that the possible influence of the first two factors is excluded. Its occurrence must be observed in objective circumstances to which it is obviously non-adapted, and at times when the subject is known to be free from any disturbing conditions.

Constitutional conditions have been defined as relatively

permanent and enduring conditions, and all modes of action that are functions of these conditions should be manifested over long periods of time and under a variety of objective circumstances. Frequency of manifestation over considerable periods of time may thus be regarded as a criterion of a trait.

A final criterion of a trait is its mal-adaptiveness to the situation in which it is manifested. A host who is persistently rude and discourteous to his guests must be regarded as a discourteous person. An individual who is courteous to both friend and foe, to subordinates as well as superiors, to strangers as well as acquaintances, and to those who treat him rudely, must be courteous by nature. As a final illustration we may cite a pathological case. A boy that persists in stealing things which he does not need and which he has the money to buy, and especially under conditions in which he knows that punishment is inevitable, is said to steal from an inner compulsion and is usually termed a kleptomaniac or pathological thief.

A trait is not an observable attribute of an individual. Only its behavior manifestations can be observed. The existence of a trait in a given individual is a matter of judgment, and such judgments may be either right or wrong. Two general conditions of the correctness of these judgments may be noted. 1. The correctness of a judgment varies with the frequency and the variety of conditions under which the mode of action has been observed. In other words, the observer with the widest acquaintance with the individual in question is the most likely to be correct in his judgments of that individual. 2. All judgments of an individual that are based upon the affective, emotional, and conative reactions of the observer are peculiarly susceptible to the personal equation. For example, an observer is quite frequently irritated by the actions and manners of several of his associates, and on this observational basis he labels these people as *irritating* individuals. This judgment may be entirely incorrect, for this particular mode of response may be an expression of the constitutional nature of the observer, and the observer himself should be adjudged an *irritable* person.

In any social situation, the constitutional nature of either of the two individuals concerned may be defined on the basis of their interaction. The judgments of any observer that are based upon this class of observational data cannot be regarded as valid until they have been confirmed by several other observers.

Conceptual nature.—The organic conditions of these trait characteristics are not accessible to direct observation. If these various conditions could be observably identified in respect to their distinctive nature and locus, we would probably specify and refer to them directly in terms of some of these distinctive characteristics. Since their distinctive nature and location are unknown, we are forced to name and identify them in terms of their distinctive behavior correlates, and then apply these terms to the individual who possesses them. However, these trait terms are not mere words. They are applied to the individual in virtue of his possession of these organic conditions, and they are thus symbols that indirectly denote those conditions. Traits are conceptual realities that are highly similar to such concepts as engrams, nerve traces, neural modifications, etc.

In the use of these concepts, there are two possibilities of error that must be avoided. 1. Inasmuch as an individual possesses a multitude of traits, we must inhibit the naive tendency to conceive of their respective organic conditions as simple and unitary in character and occupying a distinctive location within the organism. 2. An unobservable object is one that is invisible and intangible, and there is some tendency to think of invisible and intangible things as unsubstantial and immaterial in character. Any tendency to reify these trait concepts in terms of an unsubstantial and immaterial content must be inhibited in the interest of accurate and precise thinking. Any such tendency leads directly to an ontological dualism.

Generality.—Traits are general in proportion to the frequency of occurrence of the corresponding mode of action. All traits possess some degree of generality, but the degree of generality varies widely with the trait and the individual.

Probably no trait is 100 per cent general, *i.e.*, continuously present in all of our activities.

Since traits are functions of the constitutional nature of the individual, they denote modes of behavior that will be repeated in the future. A trait is thus a predictive concept, and all traits are general at least *in respect to time*.

A trait may be manifested in a very limited number of behavior situations. A person may exhibit certain traits at church but nowhere else. We may be courteous, kindly, and considerate at home, and exhibit quite diverse modes of conduct in our outside activities. We may be affable, loyal, and honest with our friends and acquaintances, and be gruff and rude in our other social contacts. Likewise other individuals may be so organized as to manifest these same traits in a great variety of circumstances. A trait is general in proportion to the variety of behavior situations in which it is manifested.

A trait may manifest itself through one motor outlet and not through another. An individual may be deliberate in thinking, speaking, walking, skating, and in the manual manipulation of objects, while in another individual this characteristic may be limited to speech. The greater the number of motor outlets, the greater the number of behavior situations in which a trait may be manifested, and hence the greater is its degree of generality.

Unity and complexity.—Like most concepts, traits are both unitary and complex in character. A trait is unitary in so far as it is an object of thought and specified by a single word. The behavior characteristic which a trait denotes is sometimes unitary. Persistence, aggressiveness, loquacity and stubbornness may be cited as possible examples. We also characterize people on the basis of some particular kind of act, as liars, thieves, and drunkards. Most traits are complex in that they denote some *pattern* of behavior characteristics. Affability, cordiality, courtesy, impressiveness, and vivacity are illustrations. Other traits are both unitary and complex in their behavior reference. Individuals are often characterized on the basis of the observer's affective and emotional reaction to them. This mode of reaction may be

unitary, and yet it is aroused by a *complex* of behavior stimuli. As illustrations, individuals are characterized as attractive, aggravating, hateful, likeable, repulsive and pleasing. Traits also denote the unknown organic conditions which are responsible for the observed characteristic of behavior. These conditions are presumably quite complex and variously located within the organism. All traits are thus complex in respect to this denotation.

Degree of universality.—Traits are universal in proportion to the number of individuals who possess them. The degree of universality varies with the trait. Only relatively few persons can be characterized as evasive, gullible, haughty, gloomy, impressive, irritable, hateful, loquacious, petulant, peevish, stupid, shy, sullen, rude, repulsive, unctuous, or vindictive. Only a few individuals can be legitimately labelled as liars, thieves, drunkards, or bullies. On the other hand, such terms as courteous, confident, honest, interesting, independent, industrious, loyal, kindly, likeable, persistent, and self-reliant can be applied to a much greater number of people.

Some traits are probably 100 per cent universal. For example, practically every individual may be legitimately regarded as possessing some degree of honesty and perseverance. Traits are popular concepts, and for practical purposes we are prone to label people as persevering and honest only when they deviate from the customary norm in some *conspicuous* manner. Because of this fact we are inclined to assume that these traits are limited in distribution, and hence fail to note their high degree of universality.

Trait relationships.—A number of traits often denote highly similar combinations of behavior characteristics, and hence these terms are quite *similar in meaning*. Presumably such traits will exhibit a high degree of correlation. It is evident that such terms as affable, cordial, courteous, agreeable, gracious, admirable, pleasing, attractive, charming, and likeable have much in common in respect to their meaning. The terms reticent, shy, reserved, sensitive, and retiring are also somewhat alike in meaning. The terms enthusiastic,

ebullient, animated, temperamental, vivacious, and excitable constitute another similar group.

Often two terms are so highly similar in meaning that they are regarded as practically *synonymous*, although in all probability no two trait names are exactly synonymous. As illustrations we may cite such pairs as adventurous and daring, frank and candid, proud and haughty, and petulant and peevish.

At the other extreme, there are pairs of traits that are regarded as *antagonistic* in character, but many of these pairs are not exactly antithetical. These pairs are often denoted by hyphenated terms. 1. Sometimes the two opposed traits are denoted by distinctive names. Moody-cheerful, sober-gay, attractive-repulsive, hateful-loveable, frank-evasive, deliberate-impulsive, domineering-submissive, modest-boastful, loquacious-taciturn, cruel-compassionate, and extraverted-introverted are illustrative examples. 2. The antagonistic trait is sometimes denoted by a suffix, and we have such antagonistic pairs as loyal-disloyal, honest-dishonest, courteous-discourteous, pleasing-displeasing, likeable-dislikeable, satisfying-dissatisfying, popular-unpopular, gracious-ungracious, and modest-immodest.

It is convenient to regard these antagonistic pairs as *units* for purposes of measurement. Consequently every individual can be located on a scale of honesty-dishonesty. Inasmuch as it is customary in every day life to label only those individuals who deviate from the customary norm in some unusual degree, there is a general tendency to assume that all individuals are *either* honest or dishonest. This assumption is contrary to fact. Since these traits are not 100 per cent general, it is entirely possible for an individual to be honest in some situations and dishonest in others. Some individuals are punctiliously honest with their friends and associates but dishonest in their dealings with others. Some are honest in all direct personal relations but dishonest with corporations and in matters of taxation. Most individuals are both honest and dishonest, frank and evasive, domineering and submissive, and loquacious and taciturn according to the situation in

which they find themselves. These pairs are antagonistic only in the sense that both cannot be manifested at the *same time*. They are not *mutually exclusive* in respect to the individual. They will be mutually exclusive attributes of the individual only when the two traits approximate 100 per cent generality. An individual is thus located on a honesty-dishonesty scale on the basis of the relative strength of these two traits. A median location on the scale denotes that the individual in question is judged to be equally honest and dishonest.

Individuals are often characterized because of their lack of a given trait. We thus have pairs of words that denote the *presence* and *absence* of a trait. Illustrative examples of such pairs are interesting and uninteresting, impressive and unimpressive, suggestible and unsuggestible, cooperative and uncooperative, assertive and unassertive, attractive and unattractive, excitable and unexcitable, sensitive and insensitive, impressionable and unimpressionable, vindictive and nonvindictive, enthusiastic and nonenthusiastic, and stimulating and nonstimulating. These pairs must not be confused with *antagonistic* traits, although in some cases it is extremely difficult to decide to which class a given pair belongs.

Strength or amount of trait.—We are accustomed to compare individuals in respect to the strength or amount of a trait which they possess in common. We judge that an individual is more honest, more persevering, more courteous, more cooperative, and a greater liar than another. The strength or amount of a trait thus varies from individual to individual. The strength of universal traits will thus vary between a maximum and a minimum. The strength of non-universal traits will obviously vary from a maximum to zero. Both members of an antagonistic pair of traits vary in strength, and a judgment of an individual in respect to such a dual scale is based upon the relative strength of the two traits concerned. As previously noted, the median location on such a scale denotes that the two traits are regarded as equal in amount.

In making these direct quantitative comparisons of two individuals, we gradually evolve some sort of a conceptual scale of values for each trait. With the development of these conceptual scales, direct comparisons are no longer necessary, for the amount of a trait possessed by any individual can be defined in terms of this scale. These conceptual scales contain at least three points of reference—the two extremes and the median position—and each individual is identified in terms of his judged location to one of these points of reference. The average is the one that is most frequently used. We judge that an individual possesses an average amount of honesty, and that he is either above or below the average in respect to affability. We are also accustomed to employ several quantitative terms to describe the amount of deviation from the average. An individual is said to be slightly above, considerably above, or very much above the average in respect to some trait. The extreme positions of the scale are also utilized as points of reference. An individual is characterized as being the most courteous person or the biggest liar whom we have ever encountered. It is evident that the range of any individual's scale of values is a function of the breadth of his social contacts, and this breadth will necessarily vary considerably from individual to individual. The median positions in such a series of scales are likely to be approximately the same, but the two terminal positions are likely to exhibit considerable variation from individual to individual. The estimations of an individual by a number of observers are thus likely to exhibit the most agreement when the median position on the scale is used as a point of reference.

Any judgment of the strength of a trait is presumably based upon certain quantitative features of its behavior manifestations. In making a judgment, the average observer has no analytical knowledge of the nature of these quantitative criteria. A knowledge of their nature must be derived by a process of reflective analysis, and we shall briefly mention some of the more important and obvious factors.

1. *Frequency of expression.*—We judge that the strength of a trait varies from individual to individual in proportion

to the frequency of its manifestation when all other relevant factors remain constant. An individual who lies persistently under a great variety of behavior situations is regarded as a bigger liar than one who lies occasionally under a limited number of circumstances. The individual who frequently manifests deliberateness, impulsiveness, petulance, pride, or shyness in all sorts of behavior situations is judged to possess these traits to a greater degree than one who occasionally exhibits these characteristics in a restricted number of circumstances. This criterion is implied in the popular characterization of a man as being as honest as the day is long.

The validity of this criterion is based upon the tacit assumption that the greater the strength of a trait, *i.e.*, the more thoroughly it is engrained in our nature, the more likely we are to manifest it. Frequency of expression is a universal criterion in that it can be used in the evaluation of any trait. The use of the criterion presupposes a considerable amount of contact with the individual in question, and hence the validity of an observer's judgment will naturally vary with the amount and variety of this contact. In the absence of such contact, our judgments must be based upon some other criterion.

2. *Duration of expression.*—Duration is a similar criterion, but it is one whose use is limited to a relatively small number of traits. Certain behavior characteristics can be manifested for varying lengths of time, and individuals differ considerably in this respect. Some individuals maintain their enthusiasm for a given task for long periods of time, while others exhibit an initial enthusiasm that soon wanes and vanishes. In such cases we are accustomed to judge that the strength of this trait is proportional to the duration of its expression when all other relevant factors are constant.

This criterion can be used to judge the strength of such traits as animation, courtesy, cordiality, friendliness, reticence, vivacity, sobriety, cheerfulness, sullenness, enthusiasm, loquacity, shyness, earnestness, pride, and confidence. Duration is especially significant for such traits as persistence, determination, and perseverance, for we are inclined to believe that the very essence of these traits is reflected in the length of

time that an individual will continue in the attempt to achieve some end.

3. *Objective results.*—The strength of a few traits may be judged in part on the basis of the objective results of their expression. We are accustomed to rate people in respect to their degree of generosity, philanthropy, and charity in part on the basis of the amount of their gifts and gratuities. Theft, cheating, and dishonesty can also be measured in monetary terms. We are also accustomed to make a distinction between big and little lies, and we use the term 'big liars' to refer to those individuals who are accustomed to deviate widely from the truth.

4. *Degree of mal-adaptiveness.*—The adaptiveness of a trait is a function of the character of its relation to the behavior situation in which it is manifested. A given trait may thus be adaptive to certain situations, non-adaptive to some, and mal-adapted to others. A mode of acting is usually termed adaptive when it occurs under circumstances which offer some good reason for so doing. Stealing food to keep our children from starving is an example. A mode of acting is non-adapted to a situation when it offers no good reason for so doing. Stealing objects which we do not need and which we have the money to buy is an illustration. A mode of action is mal-adapted when it occurs in situations which normally tend to inhibit its expression. Stealing things in broad day-light and under the very eyes of a policeman is an illustrative example, and we note that a given trait may exhibit varying degrees of mal-adaptiveness according to the situation in which it is expressed.

Individuals differ radically in the degree to which they will express or inhibit a given trait in situations to which it is mal-adapted. Some individuals will inhibit the expression of a trait in any situation to which it is non-adapted, while others will give expression to this same trait in situations to which it is highly mal-adaptive.

We assume that only a very strong or deeply engrained trait will manifest itself in highly inhibitory circumstances, and hence we are accustomed to judge that the strength of a

trait varies from individual to individual according to the mal-adaptiveness of its expression. A person who is rude to his guests is thus regarded as a very discourteous individual. A person who continues to be cordial, courteous, and gracious to those who treat him rudely and vindictively will be adjudged to possess these traits to an unusual degree. Those who maintain their confidence and cheerfulness in spite of adversities must possess those traits to a high degree. Impulsiveness must be thoroughly engrained in the reactive nature of an individual if he continues to act in that manner in situations that obviously demand a high degree of caution and deliberation.

Traits are also subject to other types of inhibitory influence. The length of time that an individual will manifest certain modes of action is a function of various distractive conditions—both objective and intra-organic in nature. An individual will find some difficulty in being persistently cheerful, vivacious and gay to his guests while suffering from an aching tooth, and patient persistence at a difficult mental task is hard to attain in a noisy environment. Individuals differ considerably in their susceptibility or immunity to such distractions, and hence we are accustomed to judge the strength of various traits such as perseverance, determination, cheerfulness and vivacity on the basis of their degree of resistance to distraction.

Teachers and parents often attempt to eliminate certain socially undesirable traits in children. They may find that one trait is quite susceptible to control, while another is so thoroughly established as to be wholly immune to these social influences. Individuals often attempt to break themselves of some undesirable mode of action, and they may find that some traits are susceptible to volitional control, while others are immune to such influences.

We thus suggest the possibility of including all the cases cited in this section under the general principle that we tend to judge the strength of traits in part upon the basis of their degree of resistance to any sort of inhibitory influence.

5. *Extent of expression.*—A trait like enthusiasm may be

expressed through a variety of motor outlets such as voice, gesture, bodily posture, and facial expression. Individuals probably differ to some extent in respect to the number of motor outlets through which a given trait is simultaneously expressed. With some individuals their vivacity and animation is largely limited to facial expression, while others are accustomed to express these same traits through all four outlets simultaneously. In so far as individuals do differ in this respect, we may use this quantitative variable as a means of judging the relative strength of the trait in question. The use of the criterion is based upon the assumption that the greater the number of motor outlets through which the trait is manifested, the more thoroughly it must be engrained in the reactive nature of the individual. This possible criterion, however, is limited to a restricted number of traits such as affability, animation, courtesy, enthusiasm, graciousness, vivacity, impulsiveness, etc.

6. *Speed of response.*—Speed of response is another possible criterion. Individuals differ materially in respect to the speed of their reactions, and it is possible that our judgments of the strength of certain traits may be based in part upon this quantitative variable. A quick response may be used as one of the indications of a high degree of alertness, impulsiveness, confidence, enthusiasm, vivacity, excitability, irritability, and rashness. On the other hand, a slow response may be used as one of the indices of a high degree of caution, reticence, deliberation, evasiveness, and stolidity.

7. *Energy of expression.*—Energy of expression is another possible criterion. Individuals express themselves with different degrees of vigor and energy, and consequently we are accustomed to characterize certain individuals as being more vigorous and energetic than others. This adverbial characteristic of behavior may thus be used as one of the quantitative criteria for judging the strength of such traits as determination, dogmatism, rudeness, pugnacity, gruffness, impulsiveness, and aggressiveness.

This analysis of the basis of our quantitative judgments of the strength of a trait does not pretend to be exhaustive,

but it is sufficient for the purpose of this paper. It is evident that our judgments of the strength of a trait may be based upon any one of a number of factors. In so far as our judgments are based primarily upon some one factor, the factor that is used is likely to vary with the observer, the trait, and the observer's experiential contact with the individual in question. It is more probable, however, that our judgments are based upon some group of such factors. Since these factors do not exhibit a perfect correlation with each other, we are at once confronted with the problem of their relative importance. The judgments of a number of observers may thus vary because they are based upon different combinations of factors.

It is evident from this analysis that our judgments of the strength of a trait are subject to a number of limitations. An observer's judgment of a given individual is likely to vary from time to time. The observer's judgment at any time will be based upon some observed bit of behavior, a distinct memory of some recent or striking performance, and a vague memory impression of all of his previous contacts with the individual. The judgment may be largely determined by the first two items, and the nature of these will vary from time to time. Likewise the particular combination of quantitative criteria that is used is also likely to vary with time. In making any judgment we are likely to remember our previous estimations of this individual, and we may note that this memory factor operates as a stabilizing influence that is conducive to consistency of judgment.

These judgments will also vary from observer to observer. This is due in part to the temporal variations in each observer's judgment noted in the previous paragraph. An individual is judged in terms of a conceptual scale of values, and this range of values will vary with the breadth of the observer's contact with the trait in question. The judgments also vary with the character and extent of the observer's contact with the individual. No two observers are likely to utilize the same combination of quantitative factors upon which to base their judgments. These judgments are also peculiarly susceptible

to the personal equation. No judgment of an individual based upon the affective, emotional and conative reactions of the observer can be regarded as valid until confirmed by other observers. Judgments based upon these reactions of the observer are likely to influence his judgment of other traits. An observer who dislikes an individual is apt to overrate his bad qualities, while those who like this individual are likely to exhibit the opposite tendency. Fortunately there is one factor that operates toward uniformity of judgment. We not only make judgments of people, but we express them to our friends and acquaintances, and in turn encounter their appraisals of these same people. Our judgments are thus being continually subjected to this social influence, and this is conducive to some degree of uniformity.

Traits and abilities.—A previous paper was devoted to the analysis of the concept of ability.[2] The two concepts are intimately related, and the nature of this relationship may be briefly stated.

Both traits and abilities are attributes or characteristics of the individual. They are concepts that are used to define the reactive nature of the individual. In both cases the nature of the individual is defined upon the basis of those observable characteristics of his behavior that are regarded as expressions or manifestations of his constitutional nature. Constitutional conditions are those that are relatively permanent and enduring, and hence both traits and abilities are predictive concepts. The individual is defined as one who has been observed to act in certain ways and who can be expected to continue acting in those ways for some time in the future.

Traits and abilities differ in respect to their behavior connotations. The concept of ability refers to the efficiency of the individual's behavior in attaining various ends, while the concept of traits refers to the way he behaves in attaining those ends. Traits and abilities thus refer to different attributes or characteristics of the same series of acts. On the basis of a series of typewriting performances, an individual

[2] H. A. Carr and F. A. Kingsbury, The concept of ability, PSYCHOL. REV., 1938, 45, pp. 354–376.

may be defined in respect to his typing ability, and these same performances may be used in judging him in respect to such traits as perseverance, attentiveness, determination, coordination, self-confidence, etc. On the basis of his comparative sales records, an individual may be characterized in respect to his ability as an insurance salesman, and these salesmanship activities will also furnish the observational data for defining him in respect to an extensive series of traits.

The concept of ability defines an individual in terms of his degree of success in meeting the various situations of life, while his traits refer to those modes of reacting to these situations which are popularly supposed to contribute to his success. An individual's abilities are thus popularly regarded as functions of his traits, and abilities are to be explained in part in terms of traits.

In every day life we are accustomed to note the relative degree of success attained by various individuals pursuing a common vocation, and we also develop some notion as to the group of traits that are conducive to these degrees of success. In this way there is gradually developed a popular notion as to the various traits that are conducive to success in each of the various vocations. On the basis of this popular knowledge, we are accustomed to make some prediction of the probable success of a given individual in any vocation he may contemplate entering. For example, teachers of psychology are continually being requested to make statements of their opinions as to the probable teaching success of their students, and we do this in part on the basis of our knowledge of their traits which we deem relevant to teaching ability. This paper holds no brief for the validity of these judgments. We are merely noting the fact that traits are used in every day life in making predictions of probable success throughout the whole range of social situations, and that this popular usage is based upon the assumption that abilities are functions of traits.

Traits may also become abilities. An individual may become dissatisfied with himself and strive to act in a more courteous, vivacious, impressive, or industrious fashion than

he is accustomed to do. Since an ability characterizes an individual in terms of his success in achieving his ends, we can legitimately characterize him in respect to his ability to act in this manner. Any trait is also an ability in so far as it becomes the object of our endeavors.

Psychological significance.—A list of about 18,000 trait names has recently been compiled. It is evident, from the preceding analysis, that most of these popular traits have some significance for the various fields of applied psychology. Does the concept of traits also possess any significance for the purpose of a general and systematic psychology? Four possibilities may be briefly mentioned.

1. The significance of the concept is limited to applied psychology, and it is of no concern to a systematic type of psychology.

2. Perhaps a systematic psychology should be concerned only with those popular traits that possess a distinctly psychological connotation such as suggestibility, inquisitiveness, alertness, and self-reliance.

3. The establishment of a trait in early life materially influences the course of subsequent development, and apparently traits differ considerably in respect to the amount and character of this influence. Perhaps a systematic type of psychology should select for study those traits that are known to exert the most pervasive and widespread effect upon the subsequent development of the individual.

4. We may note that abnormal and clinical psychology have evinced no interest in the popular traits, but have developed a set of new traits that are supposed to possess a distinctive value for their purposes. We refer to such traits as introversion and extraversion, submission and ascendency, emotional stability, mal-adjustment, and integration. Perhaps a systematic psychology should likewise be concerned with the development and study of a set of new traits that are relevant to its purposes.

An inspection of the literature reveals the fact that the concept of traits is engaging the attention of an increasing number of psychologists. Most of our present day texts are

accustomed to make some casual reference to the concept, and it is introversion and extraversion that are most frequently mentioned. Much of this literature conveys the distinct impression that psychology at present is groping somewhat blindly about because of the absence of any definite and accepted principles of orientation in reference to the concept. We are here raising the question of the function of this concept in a systematic account of mental life, without attempting to formulate the answer.

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THE MEASUREMENT OF REMINISCENCE

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The phenomenon of reminiscence, as the term is used in the experimental studies and reviews, seems to be regarded as an improvement in memory for short intervals of time in the absence of practice, and is identified experimentally with a rise in the curve of retention under such conditions. It is an improvement that is consequent upon the interval, and this meaning of the term is the one that will be used in the present paper.

The method of measuring reminiscence usually employed in the studies of this phenomenon consists of a comparison of the amount reproduced after a specified interval of time with the amount recalled immediately following the formal practice which resulted in partial learning of the material. For each subject in the experiment there is an immediate and a delayed recall test. The amount reproduced immediately after practice is taken as a base in terms of which the percentage recalled on the second test is calculated. As an index of the presence and amount of reminiscence, the arithmetic mean of the group on the delayed recall test has been used and sometimes also the relative number of subjects in the group who remembered more on the second recall than on the first. Ballard (1) employed both procedures in his study, while Williams (10) expressed his results in terms of group percentages only. In a fairly recent study of the conditions of reminiscence, G. O. McGeoch (7) expressed the view that the masking caused by using group-averages of the percentages recalled on the second test may actually conceal the presence of reminiscence, and that some times one cannot tell from the percentages of retention of the group whether any reminiscence occurred or not, and conversely, under some conditions

one cannot tell from the percentages of Ss showing reminiscence whether the group retention-score will indicate improvement or loss. After discussing these two procedures, she concludes that ". . . the percentage of Ss exhibiting reminiscence is a more valid measure of reminiscence itself than percentages derived from group-scores" (p. 74). The present paper is not concerned with the relative merits of these two procedures, but it is the suggestion of this paper that both methods are of questionable validity, and that neither one as used can be taken as an adequate measure of the amount of reminiscence.

The disturbing feature in the usual method of measuring reminiscence, present in both of the procedures just mentioned and not handled adequately in either of them, is the effect of the immediate recall upon the subsequent recall test.

The immediate recall test admittedly constitutes an additional practice period, and the most expected result from even a small amount of additional practice that is given the subject during the process of learning when the learning curve is rising fairly rapidly, is further improvement. Furthermore, the effect of the immediate recall test might reasonably vary with the degree of partial learning present at the time, the effect being greater perhaps in the early stages of learning than in the final periods of practice where the curve is leveling off as the subject's learning nears completion, just as reminiscence has sometimes been reported to vary with the degree of learning. It does not seem likely that the effect of the immediate recall test is sufficient to account for all the improvement that has been found in reminiscence data, but in so far as the effect is positive, *i.e.*, above zero, and is some undetermined amount, the actual improvement found in the delayed recall test can scarcely be regarded as an adequate and valid measure of the amount of reminiscence.

As regards the variable in question, the methodology is not essentially improved by determining the percentage of subjects in the group who show an improvement instead of a loss in the delayed recall test, and the amount of such improvement exhibited by them, instead of using the average scores

of the whole group. Trial-by-trial records for individual subjects usually show alternation of improvement and decrement throughout learning. A cross-section through the individual learning curves at some point on the abscissa representing partial learning, reveals that while many subjects have gained over their level at the preceding practice trial, some exhibit a loss. This state of affairs is present no doubt when the experimenter terminates formal practice early in order to study reminiscence. It is quite likely that the additional practice afforded the subjects in the immediate recall test may be followed by similar results. Since such results may be present at the beginning of the interval, and would be of unknown amount, the percentage of subjects exhibiting improvement and the amount shown by them on the delayed recall test appears to be no better than group percentages as a method of measuring the amount of reminiscence.

In several of the studies in this field the possible effect of the immediate recall is clearly recognized (**1**, **2**, **7**, **9**), and in those instances in which tests were made (**1**, **9**) the effect was found to be beneficial in character. As a further test of this factor, the following group experiment was conducted.

At a regular meeting of a class in General Psychology the students partially learned six stanzas (24 lines) of a poem, after which they were given two recall tests in immediate succession. Two pages of paper and a mimeographed copy of the poem were placed in front of each student. When a signal was given the subject turned the page over and memorized as much of the material as possible in the period of 10 minutes. At the expiration of this interval, time was called, copies of the poem were collected quickly, and the students wrote on one of the pages provided as much of the poem as could be recalled. The work was done quietly and ample time was allowed for recall. Upon completion of this recall test, the papers were put aside and the students asked a second time to write out as much of the poem as they could recall. This procedure is quite analogous to that employed by Ballard, Williams, et al., in studying reminiscence with the

exception that the second recall test occurred immediately after the first. The papers were scored on the basis of the number of lines correctly recalled, and the results are shown in the table.

COMPARISON OF THE FIRST WITH THE SECOND RECALL TEST WHEN THE SECOND FOLLOWS THE FIRST IMMEDIATELY

No. of Ss	First Recall		Second Recall		Diff.	Sigma of Diff.	Critical Ratio	Per Cent Improvement in Second Recall
	Perfect Lines		Perfect Lines					
	Average	σ ave.	Average	σ ave.				
105	12.03	.48	13.41	.48	1.38	.43*	3.2	11.1
Per cent Ss showing improvement in second recall			61.0					
Per cent improvement shown by these Ss			23.2					

* Based on formula which involves the correlation of the two sets of data.

The average number of lines recalled on the second test was 13.41 as compared with 12.03 for the first test. This difference of 1.38 lines represents an improvement in the second recall of 11.1 per cent. As indicated in the table, the difference score is 3.2 times its sigma. In other words, more of the partially learned material is recalled in the second than in the first recall test even though the second recall follows the first immediately. Furthermore, as when going from one practice trial to another during learning, some subjects exhibited a loss, while of those who showed improvement not all improved the same amount. The percentage of the Ss who recalled more on the second test was 61.0, and the average amount of improvement shown by them was 2.8 lines or 23.3 per cent.

Although the first recall test, introduced in the middle of the process of learning verbal material, may differ in several respects from the subject's immediately preceding repetitions in practice, the above data show that it is followed by a significant amount of improvement in an immediate retest. Reminiscence, *i.e.*, improvement in the partially learned

function that is consequent upon a time interval, is not satisfactorily measured merely by a comparison of the subject's delayed recall test with his own scores on the first recall.

A somewhat more satisfactory method of measuring reminiscence is the conventional group control procedure employed in studies of the relative economy of distributed vs. massed practice. For example, if one desired to determine the influence upon learning of a single rest period, 24 hours in length, introduced in the middle of the learning process, say after the 10th practice trial, the procedure would involve two equivalent groups of subjects: one, with the rest interval as indicated, and the other as the control condition would learn the problem under conditions of massed practice. The differences between the two groups in the amount of practice required to reach a criterion of mastery would be regarded as an indication of the value of this particular distribution of effort in this instance. Exactly the same experimental procedure would appear to be adequate for determining the presence and amount of reminiscence under the above conditions. With the two groups matched in the learning of the first ten trials, differences between the two groups in subsequent practice could be regarded as a function of the interval used. The two groups could be compared with each other on the basis of the amount of practice required subsequent to the tenth trial to reach a criterion of mastery, or on the basis of the records made on the eleventh trial. Both of these methods have been used in the study of reminiscence in motor learning, *e.g.*, the former was used in a study by Bunch and Magdsick (**3**), by Magdsick (**6**), and the latter in a study by G. O. McGeoch (**8**). More recently, Hovland (**4**), in a study of reminiscence in the retention of nonsense-syllable material, used both methods. The former measures retention by determining whether a given amount of partial learning can be utilized more effectively in the final mastery of the problem after an interval of time than immediately following the partial learning. This procedure is essentially the relearning method of measuring retention when the original learning

has been stopped at some point short of mastery. In the latter method a comparison of the two groups in performance on the eleventh trial indicates whether the efficiency on the very first trial following the interval is a function of the interval used or merely the result of continued practice. Perhaps both comparisons should be made in order to determine the extent to which the efficiency of retention is a function of a specified interval of time.

Neither of these methods of measuring reminiscence, however, is analogous to that usually employed in studying reminiscence in the retention of verbal or memory material. The procedure can be made analogous in either one of two ways, both of which involve an equivalent group of subjects as a control condition. In one method, after the two equated groups have been stopped at the same stage of incomplete learning, one group should be given a recall test immediately, and the other should have its single recall test after the interval of time. The differences between the groups in the amount recalled would presumably be a measure of changes in the efficiency of memory consequent upon the interval. A second method is indicated if the same subjects have both an immediate and a delayed recall. The control group under this condition apparently should have two recall tests also, but in immediate succession. Any differences between the groups in the amount recalled on the second recall test could be considered a function of the interval of time.

Although the method of measuring reminiscence which appears to be satisfactory is the one used in the study of the economy of distributed practice, it is not the suggestion of this paper that reminiscence is to be regarded as a special case of distributed practice. A comparison of reminiscence with the greater efficiency of learning under conditions of distributed effort (3), suggests strongly that the economy of distributed over massed practice in learning is primarily dependent upon, and hence indicates the presence of, reminiscence.

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TRANSPOSITION OF RELATIONAL RESPONSES AND GENERALIZATION OF CONDITIONED RESPONSES

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In an article entitled 'The differential response in animals to stimuli varying within a single dimension' (34), K. W. Spence develops a theory in which the transposition—or failure of transposition—of relative responses to stimuli within some one continuum is made to depend upon the generalization of conditioned responses within that continuum. Specifically, the theory assumes that (*a*) the strength of the positive—or excitatory—tendency of any stimulus adjacent to a positive or a negative training stimulus is the algebraic sum of the positive and the negative tendencies which spread to the adjacent stimulus in gradient fashion, as a result of the reinforcement of the positive and the non-reinforcement of the negative training stimuli; (*b*) up to a certain distance in the continuum, the excitatory value of an untrained stimulus adjacent to a positive or a negative training stimulus will be respectively greater or smaller than the value of the positive or the negative training stimulus itself, but a reversal of these relative values will occur beyond the certain distance; and consequently (*c*) in transposition tests the response will be relative or absolute, depending upon the distance of the test pair from the training pair, the incidence of relative responses decreasing as this distance increases. Thus, if as a result of reinforcements, a stimulus-object of 256 cm.^{2} has acquired an excitatory tendency of 10 units and as a result of non-reinforcements a stimulus-object of 160 cm.^{2} has reached an inhibitory tendency of 6 units, and, if the equation for the generalization of the two tendencies is taken as $T_s = T_r\text{-}20D_2$, where T_s is the value of the excitatory or the inhibitory tendency of the test stimulus, T_r the value of the training stimulus,

and D the distance in logarithmic units between the test and the training stimulus, then the net excitatory tendencies of the training stimuli will be respectively 4.84 and 3.16, those of the untrained stimuli 62, 100, 409, 655, and 1049 cm.[2] will be 0.00, 1.52, 6.48, 6.68, and 2.50, and the response will be relative—positive to the larger stimulus—in test-pairs 62–100, 100–160, 256–409, but absolute—favoring the smaller stimulus—in test-pair 655–1049. As experimental evidence shows transposition to be less in the direction of smaller stimuli when the smaller stimulus is the one which is reinforced, a modifying hypothesis is proposed that the range of generalization is a function of the magnitude of the training stimulus and is narrower with stimuli of smaller magnitude.

Now, rudimentary accounts of transposition in terms of generalization have been attempted before (**38**, **27**, **35**), but no account has been as complete and as painstakingly elaborate as that of Spence. Unfortunately, however, Spence has not, in his theorizing and 'logical deductions,' weighed his premises, the experimental data and the known facts of the generalization of conditioned responses. He further neglected —or was unfamiliar with—the evidence on transposition in relational and pattern conditioning,[1] formations of CRs to ratios or patterns of stimuli—where the connection between generalization and transposition is certainly more direct and uncomplicated by factors of motivation, preparatory responses, and others which operate exclusively in typical discrimination experiments.[2] But to specify the argument:

1. The tendency towards *wider* generalization is only a passing phenomenon in conditioning, characterizing its very initial stage, a stage that could hardly be called true conditioning and should properly be designated as 'conditioned sensitization.' If the conditioning is successful at all, the

[1] With the exception of Usnadze's 'Zum Problem der Relationserfassung beim Tiere' (*Arch. ges. Psychol.*, 1927, **60**, 361–390), no detailed reports of such conditioning, have been made available to non-Russian readers. The writer has prepared a summary of these experiments for publication.

[2] The fact of more complicated factors in the typical discrimination situation than in the typical conditioning set-up is well demonstrated by the much finer sensory thresholds obtained in animals through the latter technique.

restriction of the extent of generalization begins very early. No matter what specificity a conditioned response finally reaches, its progressive differentiation is the rule of its developmental history.[3] If transposition were to follow generalization in the manner that Spence proposes, it would mean that its range, too, become progressively restricted from practically the very start of the training period, something which is of course contradicted by all experimental evidence and by Spence's own results (**34**, p. 438). True, with overtraining restrictions of transposition have been recently observed (**25–26**, **30**), but this occurred only at a late stage, comparable to the disruption of conditioned responses with excessive reinforcement. During the regular learning course the transposition, as might be expected, did improve and widen with training. If anything, the relation between generalization and transposition is of an inverse nature.

2. Spence's hypothesis that the range of generalization is less with stimuli of smaller magnitude is contrary to results of previous experiments (Russian laboratories and Hovland, **21**), in which the weaker stimuli have always yielded the wider generalizations. His main curve of generalization can also claim little experimental support. Hovland's curve, constructed similarly with geometrical ratio units in the abscissa, is, for instance, quite different. It is negatively rather than positively accelerated (**20**, p. 136). In general, however, it should be said that curves of generalization seem to be quite specific to the continua experimented with. With continua of magnitude and intensity generalization appears to be more a function of the magnitude or the intensity of the tested rather than that of the trained stimulus (**28**, **21**), with much more extensive generalizations to stimuli of larger than of smaller values and a consequent asymmetricity of ordinates. With the usual tactile stimulation and particularly with sound frequencies the curves are, on the other hand, quite bell-

[3] The numerous results of the Russian laboratories have in this respect, been recently confirmed by Hovland (**22**). Hovland's curve shows, however, much less and more gradual restriction, which is probably to be ascribed to the general sensitivity of the GSR, the use of human subjects, and the special complications of the generalization of sound intensities of his study.

shaped (**10, 24, 32, 20**). At any rate, Spence's hypothetical curves are distinctly different from what experimental data would warrant.

3. In studies on relational and pattern conditioning, responsiveness to the relations or the patterns becomes gradually independent of reactions to individual components. The regular course of this conditioning is that, while in the initial stage of training the components evoke undiminished responses, they lose their effects with later development (**7–15, 29, 33**). Indeed, Beritoff's students have recently shown that it is possible to condition an animal to make one response to a pattern of stimuli and another, qualitatively different response to the individual components (**10**). True, the situation here is not equivalent to that of discrimination around which Spence's "theoretical structure" revolves, but the point to be stressed is that *animals' responses to ratios and patterns are not just a matter of mere summation.* It is difficult to conceive of any summative account that could adequately explain all the phenomena of pattern conditioning,—the separate conditionings to ratios and to their elements, and the transposition of more or less *exact*[4] ratios and patterns. Beritoff's supposition that in this form of conditioning new brain patterns must be aroused or developed is the only scientific alternative.

4. Spence puts forward as a special asset of his theory its "capacity to generate logical implications that can be experimentally tested" and criticizes the Gestalt psychologists for their vagueness, generality, and failure to "furnish experimental formulations of the problem." The writer is no champion for Gestalt psychology and finds no evidence that relational responses are universal or are a *prius* in experience. The contrary appears to be definitely the case (**12, 30**). However, the writer does not consider simple conditioning as the only generator of scientific psychological principles and maintains that a *sui generis* conception of relational responses is just

[4] It might be added that Spence's theory covers only the transposition of relative responses but not of *exact* ratios—transposing, for instance, a response to a pitch ratio of 8 : 9; the latter has been repeatedly observed (**17, 10, 19, 5**).

as fruitful in testable logical hypotheses. Should more facts accumulate about the course of transposition with training, its curve in various stimuli continua, its relation to differences between stimuli trained and to reactions transposed, its place in phylogeny and ontogeny, and the like, we shall then *know* as much about relational as about conditioned responses. No doubt, as present knowledge clearly indicates (**7–15, 30**), a close connection exists between the two types of modification, but this is in itself a matter of free investigation that may only be warped by too rigid assumptions. Forced inclusions and mechanistic oversimplifications have in the past been no less damaging to psychology than inadvertent exclusions and pluralistic overcomplications. In general, the writer does not see any ultimately insoluble contradictions between continuity and discontinuity in learning, between trial-and-error and insight, between cumulative reinforcements and sudden or saltatory changes. More and more evidence points that one may well be the qualitative emergence of the quantitative growth of the other (**12, 30**). At any rate, some synthesis of the two is by no means impossible and highly desirable.

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